# EXCHANGE RATE POLICY AND PRODUCTIVITY

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# Brief Contents

# General Introduction[1]

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Since the original work of *Solow (1957)*, total factor productivity (TFP) occupies a central role in the debates on the sources of economic growth. The earlier studies on growth accounting, which is the technique of breaking down real output growth to its sources, show that total factor productivity growth (TFPG) accounts for more than ⅓ of the overall GDP growth of developed countries. This contribution of TFPG is even higher than 50% in some Western European countries *(Christensen et al. (1980))*. But later studies on OECD countries based on more recent periods illustrate that the magnitude of TFPG has diminished. This is identified as the productivity slowdown phenomenon. Despite this fact, the share of TFPG in the growth rate of developed countries remains still very high. In contrast to advanced countries, the majority of studies on the sources of growth for developing countries demonstrate that the share of TFPG in the overall growth of output is not very high as could be thought. These works tend to show that traditional inputs accumulation (capital, labor and human capital) contributes in a non-negligible way to real GDP growth in developing countries. For example, *Krugman (1994)* and *Young (1995)* reveal that capital accumulation was the main driving engine of the growth of East Asian countries. Despite this important observation made by these pioneering researches, it is crucial to highlight that the debate on the relative importance of the contribution of TFPG and traditional factors accumulation in output growth remains still open. The reality is that authors find different results according to the methods of calculation and the variables used in their study. For instance, *Bosworth and Collins (2003)*, carrying out a very comprehensive work, discover that at the global level, the role of capital stock accumulation and TFPG are comparable although there are considerable differences in their importance through time and regions. *Mankiw et al. (1992)* demonstrate that human and physical capital accumulation account for more than ⅔ of the variations in GDP per capita in the world. Contrarily, *Easterly and Levine (2001)*, and *Klenow* *and Rodriguez-Clare (1997)* defend that TFPG contributes more to real GDP growth than traditional inputs accumulation. Notwithstanding these empirical contradictions, the importance of TFPG for the long-run economic growth cannot be overlooked. In fact, if we refer to neoclassical theories of economic growth (*Ramsey (1928), Solow (1956)* and their numerous variants), we know that long-term steady-state growth can only be achieved by a constant growth of the exogenous technological progress. These theories also stress the role of capital accumulation in the augmentation of growth for economies in the transitional dynamic stage. But this phenomenon is temporary[2] and, soon or later, the economy will reach its steady-state and when at this point, only exogenous growth of technology can keep the economy growing forward. Hence, the necessity of increasing TFPG for all countries, developed or developing, in order to sustain their long-term growth and ameliorate the living standards of their respective citizens. Endogenous growth theories for their part explain that the growth rate of the economy is determined by technological innovation, market competition, broad capital formation (combined physical and human capital), innovative creative destruction incentives, technology diffusion, product variety, etc. Thus endogenous growth theories also stress the central role of TFPG for the long-run growth.

Similarly to total factor productivity, the real exchange rate[3] plays a non-negligible role in the economy. For example, the RER is the key variable in decisions involving the balance of payments (current and capital accounts). It is an important determinant, through undervaluation and low volatility, of economic growth as depicted by recent studies *(Rodrik (2008))*. Mismanagement of the RER has also bad consequences for the economy: high RER

[2] Although this could take a long time.
[3] We will use the following abbreviations: ER for the exchange rate, RER for the real exchange rate and REER for the real effective exchange rate. The REER variable used is an external measure of RER. Please, see further below for the definition of external RER.

appreciations, excessive overvaluations, large RER volatility can affect investment decisions, undermine households and firms' choices, cause balance-of-payments disequilibrium, currency and debt crises, altogether having damaging effects for productivity, growth and macroeconomic performance in general. The RER occupies a central position in trade and exchange policies between countries and regions around the world. The recent debate about the undervaluation and/or overvaluation of the Chinese Renminbi is one ongoing example.

Having briefly reviewed the central roles that total factor productivity (TFP) and the REER play in the economy, we begin this general introduction by given the main contributions of the thesis. We think it is important to inform the reader explicitly what this dissertation brings compared to the existing literature instead of letting him alone guess what these contributions are.

# 1. Main Contributions of the Thesis

Despite the importance of total factor productivity, the REER or its associated measurements (REER volatility and REER misalignment) for the short and long-run economy, few have studied the potential link between real exchange rate and its associated measurements with total factor productivity. Also a small number have examined the channels through which these variables affect productivity. This thesis attempts to fill these gaps by providing both theoretical[4] and empirical analyzes on these important issues. To date, the works that have explored the potential nexus between REER or its associated measurements and productivity are, by date of publication: *Guillaumont Jeanneney and Hua (2003)*, *Aghion et al.*

[4] This occupies a small part of the thesis. Please, see chapter 3 and below for further details.

*(2006)*, *Benhima (2010)*, and *McLeod and Mileva (2011)*. Although these previous researches have provided many insights, this thesis attempts to contribute to this literature in various ways:

1. This thesis is the first to introduce a measurement of total factor productivity exploiting the stochastic nature of the economy[5]. All previous works assume that the economy evolves in a deterministic environment by computing either TFPG based on growth accounting, Malmquist DEA Indexes or partial productivity (output per worker). In chapters 1 and 2, we instead use techniques from the well-established literature of stochastic frontier analysis, to compute measurements of total factor productivity. Like many phenomena, we believe that economic decisions concerning inputs and the production process involve some stochastic part beyond the control of producers or the economy. Examples of these phenomena are various shocks like the rainfall, natural disasters, wars, epidemics, financial crises contagions, etc. Full description of the procedures utilized to compute TFP is given, in a specific section, in chapters 1 and 2.
2. Numerous studies involving the REER extract this variable in some databases like the World Development Indicators (WDI) or the International Financial Statistics (IFS). There is nothing wrong in doing this, but the REER provided by these databases have missing values for many countries and for several periods. This phenomenon is exacerbated particularly for developing countries which represent the majority of countries on which this thesis is focused on. To avoid this problem, we undertake a different approach consisting of computing the REER ourselves from primary data. The primary data are from the World Development Indicators, International Financial Statistics, World Economic Outlook and International Trade Centre (United Nation

[5] In the literature on the relationship between the REER or its different calculations and Productivity.

Statistics Division). The need for the computation of the exchange rate measurements comes from a CERDI project in which I was involved[6]. In this project we computed Nominal Effective Exchange Rates and REER using the following types of weights: total imports, total exports and, both exports and imports taking into account oil countries and excluding oil countries[7]. In total we computed 5 REER variables and 5 Nominal Effective Exchange Rate (NEER) variables for at least 183 countries in the world from 1980 to 2004. For this thesis I decided to extend, on my own, the periods for which the exchange rate was available. Thus I recomputed all these previous variables from 1960 to 2004[8]. The details on the calculations of the REER variables, the weights employed and, how all the primary variables entering the computation procedure are measured, are described, in a specific section, in each chapter.

3. The first chapter examines the relationship between the REER itself and TFP. There exists only one paper that studies the direct link between the REER and TFP. It was done by *Guillaumont Jeanneney and Hua (2003)* for the Chinese Provinces. This chapter attempts to extend their study in the following manners. First, it is done on a panel of developed and developing countries. Second, the TFP variable is computed from an estimation of a stochastic production function. Third, it analyzes the potential existence of a nonlinear relationship between the REER and productivity.

[6] Under the supervision of Professor Patrick Plane. I thank him for allowing me this opportunity. I also thank Martine Bouchut, Computer Scientist at CERDI, with which I've done this work. For general information, the project itself took 8 to 10 months, of intensive programming, data management and data analysis, to accomplish. The client of the project was the French Agency for Development.

[7] We take out oil for the special nature of this good which is subject to episodic volatilities which, in turn, cause an appreciation of the internal RER of the exporting countries.

[8] But in the chapters, the samples of study span from 1975 to 2004. This is motivated by two factors. First, I wanted to focus on the post Bretton-Woods Era as many of these studies involve REER volatility. Second, for many countries, the data are only available starting from 1975. The only exception to this rule is chapter 1 where the sample goes from 1960 to 1999 and uses the former CERDI REER variable since when I started this chapter; this was the only variable available at that time. This variable goes from 1960 to 1999. It is important to note for each chapter the REER utilized may differ from the one used in other chapters and also the sample of study in different chapters are not the same. This is, in part, based on the availability of data in the variables and for sake of robustness of the results.

4. To this date, there are two papers that focus on the exclusive link between real exchange rate volatility and productivity growth: *Aghion et al. (2006)* and *Benhima (2010)*. Comparatively to these previous works, chapter 2 brings a non-negligible number of elements ranging from the measurements of the variables, the methods of estimation and the samples used. Firstly, as mentioned above, I use a measurement of TFPG based on panel data stochastic frontier analysis[9] whereas the previous studies employ output per worker as a calculation of productivity. Thus a measurement of partial productivity instead of TFP. Secondly, I introduce two measurements of REER volatility that have not been used before. All the previous researches utilize the standard deviation of REER as a measurement of volatility. The first measurement of REER volatility I use is obtained by regressing the REER on is past value and a tendency[10]. This variable appears to capture more accurately the volatility of the REER since it is computed relative to a tendency and an autoregressive process whereas the standard deviation is obtained comparatively to a fixed mean (i.e. a flat value) in the corresponding time window. This way of computing the REER volatility is based on *Combes et al. (1999).* The second REER instability variable is calculated as the *Fano Factor* named after the physicist *Ugo Fano* who invented it *((Fano (1947))*. Briefly, it represents the ratio of the variance to the mean of a random phenomenon in some time window. Like the coefficient of variation, it is a measure of the dispersion of a distribution. But it advantage is that it has the same unit of measurement as the original variable from which it is derived. Despite its simplicity, it is the first time that this variable is employed as a measure of volatility in all the field of

[9] Stochastic frontier analysis is a technique of estimating a production, cost and profit functions by assuming the existence of both inefficiency and stochastic disturbances affecting the frontier. See further below for more details.

[10] Please, see the section devoted to the calculation of this variable, in chapter 2, for further details.

Economics. I am not aware of any other work that has done it. Thirdly, the previous studies employ an interaction of real exchange rate volatility and financial development to capture the possible nonlinear impacts of real exchange rate volatility on productivity growth. To address this problem, I utilize the *Hansen (1999)* method of estimating thresholds effects in non-dynamic panel data. I believe that this method can capture more effectively the possible existence of nonlinearity[11].

5. In the third chapter, I study the link between REER volatility and investment. In the first chapter, I provide some theoretical arguments on the channels through which the REER can affect productivity. One of the identified channels is through private investment, public investment and Foreign Direct Investment (FDI). Hence it was necessary to study the connection between REER volatility and investment in a detailed manner to examine to what extent this hypothesis is corroborated by the data. Comparatively to previous studies on this relationship, this chapter attempts to bring the following contributions. In the first part, the theoretical section, the chapter introduces a small open economy model where investment is subject to adjustment costs. But I assume that both prices and interest rates are given, and the firms import capital goods rather than intermediate goods. I think these assumptions are more in line with the realities of developing countries than assuming the presence of pricing power for their firms. The chapter also explores the theoretical interaction between REER and investment in the presence of uncertainty but I maintain the above assumptions and add a last one, which states that investment is based only on expected per-period profits. Less importantly, the model is formulated in continuous time, contrary to the discrete time specification of previous studies. In the

[11] It is important to mention that the calculation of all the variables used in this thesis, the collection and construction of the various databases employed in all chapters, the construction of the graphs and the tables presented in this thesis are done by the author alone.

second part, I investigate, empirically, the link between REER volatility and investment using Panel Data Cointegration Techniques. The previous studies on this relationship use microeconomic panel data methods (Fixed Effects, GMM, etc.) on annual data with relatively long periods. But given the presence of potential unit roots in the variables, these estimations could be seriously affected by spurious regressions phenomena. This is why I believe Panel Data Cointegration Techniques could be more appropriate in this situation. Also these methods have other advantages over short-term panel methods and on time series techniques. The chapter provides some arguments on these useful benefits.

6. In chapter 4, we continue to explore the channels through which the REER or its associated measurements acts on productivity. As we mentioned above, chapter 1 provides some arguments about these channels. The second important channel proposed is through exports or openness in general. That is why this last chapter investigates the effects of both REER volatility and REER misalignment on exports. The main contributions are, first, the use of panel data cointegration techniques. It is also important to mention that I utilize a different estimation technique than in chapter 3. Second, I employ a measurement of REER volatility which has not been used in previous works studying these specific links. Also the misalignment variable is measured by exploiting the panel data cointegration framework.

Having exposed what this thesis has attempted to contribute relative to the existing literature, I now turn to a brief summary of the concepts of total factor productivity and exchange rate. It is difficult to perform a study on productivity and the exchange rate without informing the reader what these concepts are. A serious study on these concepts need thus to define them and explain how they are measured. This is what the following two sections do.

## 2. Total Factor Productivity

Total factor productivity measures all the contributions in total output that are not directly instigated by traditional inputs accumulation (labor or capital for example). To simplify, the TFP of an economy, is an index of the ratio of the produced output and the total inputs used at some point in time. As we will see in chapter 2, total factor productivity growth itself can be decomposed into many components like technical change, scale effects, technical efficiency change and allocative inefficiency. Hence TFPG can be viewed as an economy technological progress, the efficacy by which it combines its inputs to make output, the effectiveness by which it distributes its production factors and the economies of scale it possesses.

Since *Solow (1957)*, there exist many methodologies for computing TFP. Following the survey of *Del Gatto et al. (2011)*, we can classify them into deterministic and econometric approaches (Parametric and Semi-Parametric). Each of these techniques is distributed in turn between frontier and non-frontier procedures and some of them can be implemented on both microeconomic and macroeconomic data. Good surveys and comparisons of these methodologies are given by *Hulten (2001)*, *Van Biesebroeck (2007)*, *Del Gatto et al. (2011)* and *Van Beveren (2012)*. Following *Del Gatto et al. (2011),* I will give a brief description of each of these techniques without going deep into the details since I will only use stochastic frontier and, to some extent, growth accounting approaches which are thoroughly explained in the first and second chapter.

- ***Growth Accounting**:* Growth accounting is a technique of calculating TFP as the residual of real GDP growth that cannot be explained by the growth rate of inputs used in the production process. It is a deterministic methodology and is mostly applied in macroeconomic data with a single or cross-section of countries. It can measure TFP in growth rate or in level. Some notable works on this framework are: *Abramovitz (1956)*, *Solow (1957)* and, *Hall and Jones (1999)*.

- ***Index Numbers:*** A TFP index number is the ratio of the output index to the input index. These latter two indices can be computed according to *Laspeyres*, *Paasche*, *Fisher* and the *Törnqvist* formulas. Index numbers are deterministic, non-frontier techniques and can be applied to both macroeconomic and microeconomic data. A thorough analysis of index numbers is given in *Coelli et al. (2005)*.
- ***Malmquist and DEA methods:*** The Malmquist Index allows the decomposition of TFP, mainly[12], into change in technical efficiency and technological progress between two adjacent periods. Its empirical implementation requires the use of Data Envelopment Analysis (DEA) which relies on the computation of distance functions (Outputs or Inputs distance functions). Generally, distance functions are measured by using linear programming techniques. DEA is a deterministic frontier approach and can be used with both microeconomic and macroeconomic data. The Malmquist productivity index was first implemented by *Caves et al. (1982)*.
- ***Growth Regressions:*** The growth regressions method can be described as an estimation of a growth equation. It comes from the empirical growth and convergence literature which took impetus from the early 1990s. This approach is to estimate an equation and recover TFP from the estimated parameters and some predicted values of this equation. It employs various econometric estimation methods: OLS *(Mankiw et al. (1992))*, Panel Data Fixed Effects *(Islam (1995))*, GMM, etc. Growth regressions techniques are

[12] More TFP components can be derived, see *Coelli et al. (2005)*.

econometric, non-frontier approaches and are generally employed only on macroeconomic data.

- ***Proxy-variables Methodologies:*** As their name suggests, these procedures estimates an econometric equation in which firms' unobservable productivity is expressed as a monotonic function of observable proxy-variables: investment *(Olley and Pakes (1996))*, intermediates goods *(Levinsohn and Petrin (2003))*. These techniques are econometric (semi-parametric), non-frontier methods and are exclusively applied on microeconomic data.
- ***Stochastic Frontier Analysis:*** This method estimates a frontier (production, cost or profit function) by assuming the existence of both inefficiency and stochastic disturbances affecting this frontier. TFP is calculated from the estimated parameters, some predicted values of the variables and prices information if available. Unlike the previous econometric methodologies it takes account the presence of inefficiency in the production process and contrarily to DEA methods is conducted in a purely stochastic context. Stochastic frontier analysis is a well-established econometric method among econometricians and has become, to some extent, a sub-branch of econometrics. Like DEA methods, it permits the decomposition of TFPG into many components with the benefit that it exploits the stochastic nature of many economic decisions. These advantages are the reasons why I decided to employ, in this thesis, Stochastic Frontier Analysis compared to other techniques. As I already implied, Stochastic Frontier Analysis is an econometric (parametric), frontier method and is applied to both microeconomic and macroeconomic data. There exist many references on Stochastic Frontier Analysis but one of the most complete about this subject is *Kumbhakar and*

*Lovell (2000)* which gives an historic and encyclopedic view, many derivations and decompositions of TFPG, and numerous guides and references to the literature.

At this point, it is important to give a brief explanation on the inputs variables we employed in the estimation of production functions. The traditional inputs used at the macroeconomic level for estimating frontiers are physical capital, labor and human capital. In this thesis, I utilize only capital and labor as inputs. With this specification, education attainments are part of TFP. I did not include human capital because the data available for this variable are either very poor or there exists a lot of missing values. Furthermore many studies point the fact that human capital does not affect directly production but influence it through its impact on TFPG. The details on the measurement of capital and labor are given in chapters 1 and 2.

Let's now turn to a brief description of the RER and its associated measurements.

# 3. The Real Exchange Rate

The real exchange rate is, traditionally, defined in two different ways:

- The internal real exchange rate is the ratio of the price of domestic tradable goods to the domestic price of non-tradable goods in a particular country. A good is tradable if its price is determined in the international market while it is non-tradable if its price is not fixed internationally. Due to technical and practical problems associated to the concepts of tradable and non-tradable goods, the internal RER is not, generally, measurable empirically and is used more often in theoretical analyses. But, in the studies related to developing countries, the internal RER is the most suitable and the most generally employed measurement. There are certain studies that try to calculate the internal RER by using some proxy-variables methods. An increase in the relative price of the tradable goods is a depreciation of the internal RER.

- The external real exchange rate is the ratio of the foreign aggregate price index (or cost level) to the home aggregate price index (or cost level) converted to the same currency by employing the nominal exchange rate. The aggregate price index could be the Consumer Price Index (CPI) or the GDP deflator while the cost level could be unit labor costs. This concept of RER is used in both theoretical and empirical studies. According to the price or cost index utilized, we can have three alternative ways of computing the external RER *(Hinkle and Montiel (1999))*. The first one is the Expenditure-PPP based external RER which is calculated by using representative expenditure-based indices (which includes goods imported and locally produced and sold). The Consumer Price Index (CPI) is largely employed as a representative expenditure-based index. The CPI includes both tradable and non-tradable goods. This method of computation of the external RER is grounded on the relative Purchasing Power Parity (PPP) theory. This theory postulates that the nominal exchange rate is proportional to the ratio of the domestic and foreign price values. Due to the availability of the CPI, this type of external RER is widely used, in both developed and developing countries. The second category of external RER is the Mundell-Fleming or Aggregate Production Cost measure. In this form of external RER, the price index is a production price or cost index which incorporates goods locally produced and sold, and exports. It captures the competitiveness of all tradable and non-tradable goods. Given this reason, the GDP deflator is employed for the calculation of this type of external RER. The Mundell-Fleming model states that the GDP and exports constitute the same good and their price are highly correlated. By this assumption, it can be shown that this category of external RER is equal to the terms of trade (TOT). This type of external RER is more appropriate for developed countries where the TOT do not change very much contrarily to developing countries where the TOT are, mostly, exogenous. The third external RER is known as the external RER for traded goods. As its name suggests this category of external RER concerns uniquely tradable goods. Hence it employs output price, production or factor cost indices for the tradable goods only. It captures the competitiveness among the tradable goods only. For its empirical implementation, the following prices or cost aggregates have been suggested: value-added deflators for manufacturing goods, unit labor costs for manufacturing goods, unit values of exports, the wholesale price index (WPI). This kind of external RER is, generally, computed only for developed countries.

In most studies, interest lies in the external RER through the real effective exchange rate (REER). The REER is, generally, computed as a geometric weighted mean of the nominal bilateral exchange and the ratio of CPIs in the home and partner countries. The nominal bilateral exchange rate is the ratio of the partner countries nominal exchange rate and that of the home country. The REER is calculated compared to a certain base period carefully chosen by the researcher. The geometric mean is specifically used due to its properties like symmetry and consistency. The arithmetic mean is severely influenced by the base period and has to be re-based when performing trend analysis. Contrarily, the geometric mean does not depend on the base year chosen. Also, the geometric mean handles very large appreciation and depreciations symmetrically, while the arithmetic mean attaches a great importance to these phenomena. The weights employed in the computation of the geometric mean are, usually, the trade weights between the home country and its partners. Three types of weights are commonly used: exports weights, imports weights and total trade weights. The exports weights are the ratio of exports of the home country to a particular partner and the total exports towards all its partners. The imports weights of a home country are the ratio of imports from a particular partner and the total imports from all its partners. Total trade weights of a domestic country are the ratio of total trade (imports and exports) from and towards a particular partner and, the total trade from and towards all its partners. These weighting schemes can be improved by incorporating third-country competition and unrecorded trade. Third-country competition is the competition that two countries that are not direct trade partners deliver themselves in a third-country. Unrecorded trade, as its name suggests, is trade that is not officially recorded in the statistics of a particular country due for example to the existence of parallels markets, large tariffs and nontariff barriers to trade. Another important point to take into account when calculating the REER, is the presence of hyperinflation in the domestic country or its partners. In fact, hyperinflation could seriously bias the computed REER and cause divergence in the NEER and the REER. In the computation of the REER, the most widely method utilized when dealing with hyperinflation is the omission of the concerned countries. Good studies of the REER or its associated measures are provided in *Hinkle and Montiel (1999).*

In this thesis, we employ the CPI completed by the growth rate of the GDP deflator when the CPI is missing. The weights are direct trade weights, thus we do not adjust for third-country competition and unrecorded trade. These choices were carried out with the aim of covering a very broad number of countries than the World Development Indicators (WDI), the International Financial Statistics (IFS) or other Databases. Also the weights are calculated at the end of the period of study in order to focus on the competitiveness of the most recent years. This weighting scheme amounts to the creation of a Paasche index which allows taking into account the appearance of new countries in the global trade of the different nations in the external REER Database. More details on the computation of the REER (including formulas), the choice of specific weights and prices are given inside the different chapters. Details on the computation of the associated measurements of the REER (REER volatility and REER misalignment) are also provided therein.

This general introduction would be incomplete if we do not give the principal results found in the thesis. This is why the next section gives a short outline of the results found in the dissertation.

# 4. Main Results Found

In this section, we briefly review the main results found in this thesis. The main question is does the REER or its associated measurements affects TFPG? The secondary question is what are the channels through which the REER or its associated measurements act on TFPG? In attempting to respond to these questions, we found the following results:

- Chapter 1 studies, in panel data, the relationship between REER and TFP on a sample of 68 developed and developing countries for the period 1960-1999. The results show that an exchange rate appreciation causes an increase of TFP. The results also illustrate that this effect of REER on productivity is non-linear: threshold effect. Below the threshold exchange rate reacts negatively on productivity while above the threshold it acts positively. Robustness analysis demonstrates that these results hold both in subsamples of developed and developing countries.

- Chapter 2 employs panel data instrumental variable regression and threshold effect estimation methods to study the link between REER volatility and TFPG on a sample of 74 countries on six non-overlapping sub-periods spanning in total from 1975 to 2004. The results illustrate that REER volatility affects negatively TFPG. We also found that REER volatility acts on TFP according to the level of financial development. For very low and very high levels of financial development, REER volatility has no effect on productivity growth but for moderately financially developed countries, REER volatility reacts negatively on productivity.
- Chapter 3 examines the link between the real exchange rate volatility and domestic investment by using the panel data cointegration techniques. The theoretical part shows that the effects of both RER and exchange rate volatility on investment are nonlinear. The empirical part illustrates that the exchange rate volatility has a strong negative impact on investment. This outcome is robust in Low-Income and Middle-Income countries, and by using an alternative measurement of exchange rate volatility.
- Chapter 4 uses panel data cointegration techniques to study the impacts of real exchange rate misalignment and real exchange rate volatility on total exports for a panel of 42 developing countries from 1975 to 2004. The results show that both real exchange rate misalignment and real exchange rate volatility affect negatively exports. The results also illustrate that real exchange rate volatility is more harmful to exports than misalignment. These outcomes are corroborated by estimations on subsamples of Low-Income and Middle-Income countries.

The remaining of the thesis is structured as follows: the first part examines the relationship between the REER or its associated measurements and TFP (chapter 1 and chapter 2). The second part explores the transmission channels of the REER or its associated measures to productivity (chapter 3 and chapter 4). The last part gives the General Conclusion.

# PART I:

# THE RELATIONSHIP BETWEEN THE REAL EFFECTIVE EXCHANGE RATE, ITS ASSOCIATED MEASUREMENTS AND PRODUCTIVITY

# Chapter 1:

# Analyzing the Link between Real Exchange Rate and Productivity

# 1.1 Introduction

The theoretical analysis of the relationship real exchange rate-productivity suggests a double direction link. On the one hand, real exchange rate acts on productivity and on the other hand productivity affects the real exchange rate.

In the first case, real exchange rate appreciation can act positively or negatively on productivity.

Many arguments have been proposed to explain how real exchange rate acts positively on productivity. First, real exchange rate appreciation reduces the relative price of imported capital, carrier of technological progress. Second, real appreciation increases the real remuneration of work which involves an increase of the productivity of this one *(Leibenstein (1966), Harris (2001))*. Third, by increasing foreign competition, real appreciation can push domestic firms to be more efficient *(Krugman (1989))*.

Real exchange rate appreciation can also be unfavorable to productivity. Initially, real exchange rate appreciation can slow down export expansion. This lowers commercial openness too vital to productivity. Then, real appreciation by slowing down domestic investment and Foreign Direct Investment (FDI) can slow down technical progress. In end, if production factors are not substitutable, the increase of wages caused by real appreciation involves a bad allowance of production factors.

In the second case, productivity acts on real exchange rate. This is known as the *Balassa-Samuelson* theorem (*Balassa (1964)* and *Samuelson (1964)*). This theorem stipulates that the growth of the income of a country is accompanied by high productivity in the sector of tradable goods. It results an increase of the relative price of non-tradable goods, i.e. an appreciation of the real internal exchange rate.

This chapter studies the effect of real exchange rate on total factor productivity on a sample of 68 developed and developing countries on the period 1960-1999. This relationship was studied for the Chinese provinces by *Sylvianne Guillaumont and Hua (2003).* The chapter distinguishes itself from this previous work in three ways: first it is conducted on a panel of countries instead of provinces in one country, second the productivity variable is calculated using a Cobb-Douglas stochastic production function frontier instead of a Malmquist DEA index and third it takes account for the existence of a potential nonlinear effect between real exchange rate and total factor productivity.

The results show that an appreciation of real exchange rate results in an increase of total factor productivity. The results also illustrates that this effect of real exchange rate on productivity is nonlinear. Robustness analysis demonstrates that these results hold both in subsamples of developed and developing countries.

The chapter is organized as follows: the second section exposes the theoretical framework, the third gives the main determinants of productivity, the fourth is about the stylized facts on the real effective exchange rate and productivity, the fifth presents the calculation of total factor productivity, the following two sections speak about the econometrics models and estimations methods, and the data and variables respectively. The last three sections give the results, the robustness analysis and the conclusion respectively.

# 1.2 Theoretical Framework

The theoretical analysis of the relationship real exchange rate-productivity suggests a double direction link: one the hand, real exchange rate acts on productivity and on the other hand, productivity acts on real exchange rate.

## 1.2.1 Effects of Real Exchange Rate on Productivity

Real exchange rate appreciation can act positively or negatively on productivity according to the cases *(Sylvianne Guillaumont and Hua (2003))*. The following subsections discuss how this can happen.

### 1.2.1.1 Positive effects of real exchange rate appreciation on productivity

Real exchange rate appreciation can increase productivity *(Krugman (1989), Porter (1990)*). Many arguments have been proposed to explain this fact.

First, as real exchange rate appreciation is a result of an increase of the relative price of non-tradable goods, real wages will increase insofar as they constitute an important part of the price of non-tradable goods. Real exchange rate appreciation has hence a consequence of dropping the relative price of capital. This involves a reorganization of firms' production structure by an increase of capital intensity which in his turn increases technical efficiency. This drop of the relative price of capital also involves an increase of imported physical capital carrier of technological progress and increase of labor productivity.

Second, real exchange rate appreciation increases real remuneration of labor. According to the theory of wage efficiency, real wage conditions the effort provided to work, hence workers' productivity.

In fact, the increase of workers real wage involves an increase of their income which allows them to better take care of themselves, to educate and increase their wellbeing in general. This acts in a positive way on the motivation of workers which in his turn exerts a positive influence on the effectiveness of the combination of productive factors by a reduction of X-inefficiency *(Leibenstein (1966), Harris (2001))*. The increase of real wage involved by real exchange rate appreciation also reduces the *brain drain* because the skilled workers are incited to remain in their countries of origin. This results to an increase of workers' productivity and a greater assimilation of the innovations.

Third, real exchange rate appreciation increases foreign competition which pushes domestic firms to increase their effectiveness to remain in the market. Two effects are expected from foreign competition. On the one hand, foreign competition allows a redistribution of the resources from firms or sectors not very productive towards more productive firms or sectors. This is the phenomenon of creative destruction: the factors of production undergo a redistribution which leads to the increase in the total efficiency of the productive system so that the more efficient firms and sectors remain on the market whereas the less efficient firms and sectors disappear. On the other hand, foreign competition results in the introduction of a new non-cooperative actor into the market which threatens the position of the national firms, which pushes them to be more efficient *(Krugman (1989))*. The explanation of *Krugman (1989)* is based on the theory of the contracts applied to the firms. In a company, the manager does not have the same motivation as the shareholder because he benefits only a part of the profit generated by the company. What interests the manager is the maximization of its utility function which has two variables: part of the profit and the effort he provides. Thus although the shareholder fixes the contract so that the preferences of the manager are the closest possible to his (incentive constraint), the manager always has a certain room which enables him to deviate from the principle of maximization of profit sought by the shareholder. The introduction of a new non-cooperative actor (foreign) into the national market, transforms the effort provided by the managers into a strategic variable. The foreign firm can dominate the market by choosing a very high level of effort. The national firms conscious of this threat increase their level of effort to the risk of disappearing from the market. The shareholder of the national firm could also take the level of effort provided by the foreign managers as a scale. *Krugman (1989)* applied this reasoning to explain the effects of the overvaluation of the dollar and the pound at the beginning of the eighties respectively in the United States and in the United Kingdom. According to this explanation, the overvaluation of the real exchange rate of these two currencies during this period generated an increase in competition improving the marginal effect of effort which generated an increase in the effectiveness of management and an improvement of productivity.

#### 1.2.1.2 Negative effects of real exchange rate appreciation on productivity

Real exchange rate appreciation can be unfavorable to productivity.

In the first place, real exchange rate appreciation exerts a negative impact on exports. However, according to *Feder (1983), Guillaumont (1994),* the tradable goods sector to which exports belong is more competitive than that of the non-tradable goods since it faces international competition. A redistribution of production factors in direction of the tradable goods will have as a consequence an increase in productivity. Hence, real exchange rate appreciation involves a fall of allocative efficiency insofar as it generates redistribution of production factors towards the non-tradable goods to the detriment of the tradable goods.

In the second place, many work in particular *Findlay (1978), Wang (1990)* and *Boreinsztein et al. (1998)* showed that Foreign Direct Investment (FDI) or domestic investment in general, by involving the adoption of new leading-edge technologies, the increase in the human capital and the adoption of effective methods of management, exert a positive effect on total factor productivity via their impact on technological progress. *Boreinsztein et al. (1998)* stress that the impact of the FDI on economic growth is higher than that of domestic investment in countries that have a sufficient level of human capital. Since real exchange rate appreciation reduces profitability in the sector of exports, it slows down the FDI, investment and thus technological progress.

In the third place, if production factors are not substitutable, the real wage increase caused by the real exchange rate appreciation involves a bad allowance of production factors.

### 1.2.2 The effects of Productivity on Real Exchange Rate: The Balassa-Samuelson Theorem

Works completed in a separate way in 1964 by *Balassa (1964)* and *Samuelson (1964)*, showed that real exchange rate fluctuations can be explained by the “theory of real trade”. This explanation was called thereafter the theorem of *Balassa-Samuelson*. The idea of the theorem is that the growth of the income of a country is accompanied by higher productivity in the sector of tradable goods than in the non-tradable goods sector. This pushes the wages in the tradable sector to go upward. This in turn spills over to the non-tradable goods sector and induces an upward pressure on wages. Larger wages in the non-tradable goods sector increase the relative price of these non-tradable goods because the price in the tradable goods sector is identical through countries and internationally determined. This result implies an augmentation of home inflation which causes the REER to appreciate. The theorem thus explains why countries with high growth rate tend to know an upward trend of their relative prices and consequently of the actual value of their currency in terms of foreign currencies. In other words, such countries often know a tendency to the real appreciation of their currency. This also means that economic growth convergence across countries tend to appreciate the REER. The appreciation of the REER explained in the Balassa-Samuelson effect might or not cause a loss of competitiveness of the concerned countries. All depend on the relative significance of the productivity gains generated by economic growth and the relative importance of the tradable and non-tradable goods sectors. For instance South East Asian countries enjoyed tremendous growth in past four decades but they did not lose their competiveness in many sectors however. This is because as the country grows rapidly, it specializes in the production and exportation of goods with high value added content. Again for example, between 1960 to 2010 South Korea has passed from an agrarian economy to a big industrialized country without generally losing big market shares in international trade.

I would like to draw the attention of the reader that this chapter analyzes the link between the level of REER and productivity while the next studies the connection between REER volatility and TFPG. The evolution of REER affects its mean while the volatility of REER acts on its standard deviation, i.e. the fluctuations of the level of REER around its mean.

## 1.3 The Main Determinants of Productivity

Now I will give a brief review of the main determinants of TFP. The choice to present these determinants is relevant by the fact that the existing studies on productivity and on its links with the REER do not discuss at all the main determinants of productivity. We believe that we cannot expect a serious study on productivity without given a description of the potential factors that affect it. There exist many factors that act on productivity but the principal ones are:

- ***Financial development:*** Financial development acts on productivity, mainly, by two different methods. The financial sector by pushing individuals to save more increases the rate of capital accumulation which could enhance productivity and growth. Financial development allows the accessibility of cheap finance which motivates innovations and thus improves productivity.
- ***Openness (including Exports):*** Openness including exports increases productivity by providing more efficient techniques of production to the home country, by enhancing competition, innovation, technology diffusion and specialization, by increasing product varieties and Foreign Direct Investments (FDI) inflows, and by augmenting the scale economies. One of the assumptions made in this thesis is that the REER and its associated measurements affect productivity through openness including exports.
- ***Human capital:*** In practical implementations, human capital is, generally, assimilated to the degree of education of the people that makes up an economy. Human capital theory

assumes that education increases the marginal product of labor. It also defends that education augments productivity by facilitating innovation and imitation of technology. Human capital reduces adjustment costs of investment incurred by the firms since educated people are capable of adopting new technologies more quickly and effectively than simple workers. Human capital plays an important role in technology diffusion and advanced Research and Development (R&D) which are among the first driving forces of technological progress.

- ***Government consumption:*** Government consumption can have both positive and negative effects on productivity and growth. If it is utilized for non-productive purposes, it may hinder productivity by reducing the quantity of credits available for the private sector. Conversely, when employed in a productive way, it enhances productivity and growth by augmenting the profitability of private activities through the provision of public goods. Most empirical studies on cross-section or panel data tend to illustrate that government consumption acts negatively on productivity and growth.
- ***Inflation:*** Since the genesis of macroeconomics to today, most economists agree that inflation has social costs. Yet they do not agree, entirely, how these costs are generated and what is the optimal rate of inflation for the economy. Despite these disagreements, many studies have identified some important channels through which inflation affects productivity. By blurring the price system, inflation leads producers to make mistakes and choose the wrong combination of inputs, resulting in lower productivity compared to the optimal case *(Jarrett and Selody (1982))*. Inflation reduces the information content of prices and breaks their coordination mechanism, delaying productivity gains *(Friedman (1977))*. Inflation by increasing uncertainty may prompt producers to increase

unproductive stocks and reduce long-run expenditures on R&D *(Mansfield (1980))*. Inflation reduces after-tax profits, which, in turn, shrinks the accumulation of private capital, leading to lower Productivity. Hyperinflation increases human resources devoted to the financial sector at the expense of other sectors, thus reducing productivity *(Leijonhufvud (1977))*. The analysis of the relationship between inflation and productivity also raises the question of the optimal inflation rate for productivity because since *Tobin (1972)*, there is a huge literature that highlights the beneficial effects of "moderate" inflation.

- ***Tendency of terms of trade:*** The tendency of terms of trade is the growth rate of terms of trade (TOT). An increase of the TOT allows a country to acquire larger quantities of production factors, and invest in more technologically effective and competitive production processes which enhance productivity and growth. But TOT can also have negative impacts on productivity and growth. This comes from the natural resources curse literature which argues that augmentations of TOT could create rent-seeking activities which are, in most cases, inefficient and unproductive, leading to little productivity and growth. Most empirical studies discover that the tendency of terms of trade acts positively on TFP and growth.
- ***Crises:*** Crises represent either banking or financial crises. Crises augment uncertainty, intensify job losses and firms bankruptcy, increase social pressures and, deter investment and FDI, all of which damage productivity and growth. Other researchers support the view that crises can raise long-term productivity and growth by creating the opportunity to undertake reforms that was not possible to do in the past. Many empirical works find a negative relationship between crises and productivity.

- ***Investment:*** Most new growth theories stress the importance to interpret the capital stock more broadly. Since capital stock is the result of the accumulation of investment over the years, this implies that investment should also be considered more broadly to take account the acquisition of any asset or service that can create future production returns. This definition implies that investment comprises the purchase of tangibles assets, education and R&D. These activities are carried out by firms, individuals and governments in order to increase their future gains which, consequently, contribute to long-run productivity and growth. Another component of the assumptions made in this thesis is that the REER and its associated measurements act on productivity through investment.

In addition to these variables mentioned above, several others can be identified as being potential determinants of productivity. For example we have: Foreign Direct Investment (FDI), Foreign Debt, Population Growth, Budget Deficit, Expenditures on Education, etc. In this chapter we choose only a subset of these potential determinants of productivity. The others are employed in chapter 2.

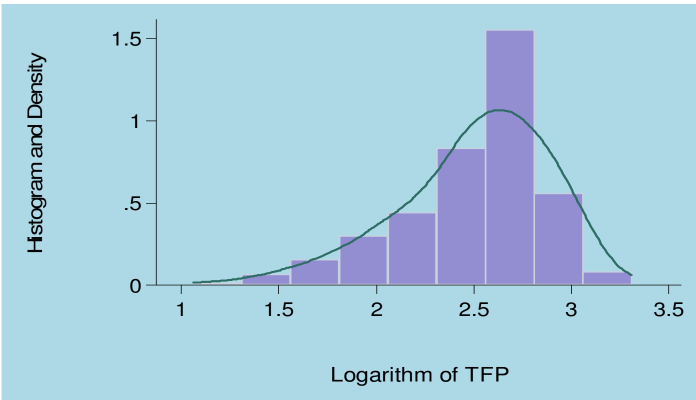
## 1.4 Stylized Facts on the Real Effective Exchange Rate and Productivity

In this section, we analyze some stylized facts on the REER and productivity.

- ***Distribution of TFP across Countries for the Overall Period 1960-1999:***

Figure 1.1 gives the distribution of the logarithm of TFP across countries for the overall period 1960-1999. The graph contains both the kernel density plot and the histogram of TFP. We observe that TFP is roughly peaked as the normal distribution but is very left-skewed (negative skew). The negative skew property of the distribution of TFP means that the left tail is longer. The distribution of TFP has relatively few low values and, almost, all the mass of the distribution is focused on the right of the figure, meaning that there are more countries with TFP above the mean. This is corroborated by the fact the median of TFP, 2.60, is superior to the mean, 2.50.

**<u>Figure 1.1:</u> Distribution of TFP across Countries for the Period 1960-1999**



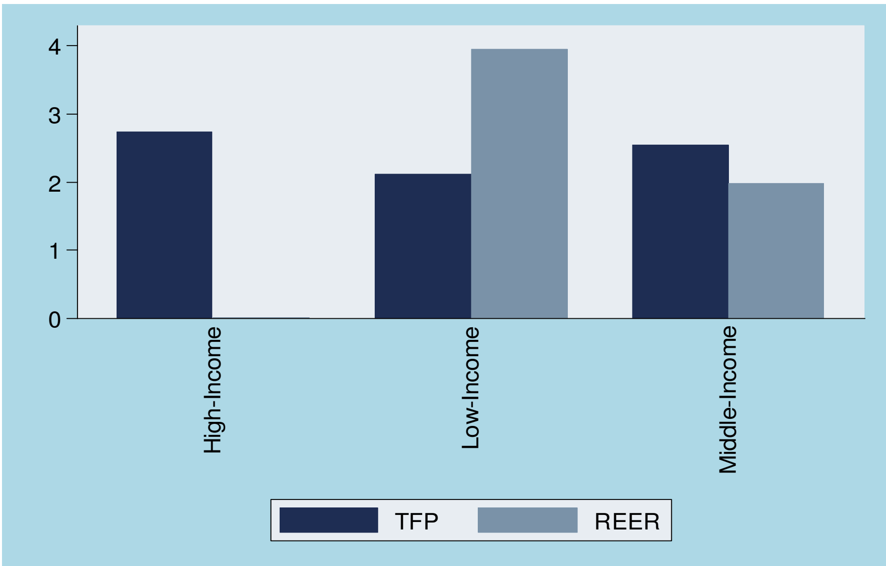

Note: The value used here is the logarithm of TFP. The period of study is 1960-1999. Source: Author's calculations.

- ***The TFP in Function of the Level of the Real Effective Exchange Rate According to the Level of Income:***

Figure 1.2 illustrates that there exist a positive correlation between TFP and the level of REER depending on the level of per capita income. We find that Low-Income countries and

Middle-Income countries that have very high REER also recorded the highest Productivity. Contrarily, the High-Income countries experience low REER rates and relatively high productivity.

**<u>Figure 1.2:</u> The TFP and the Real Effective Exchange Rate according to the level of Income**

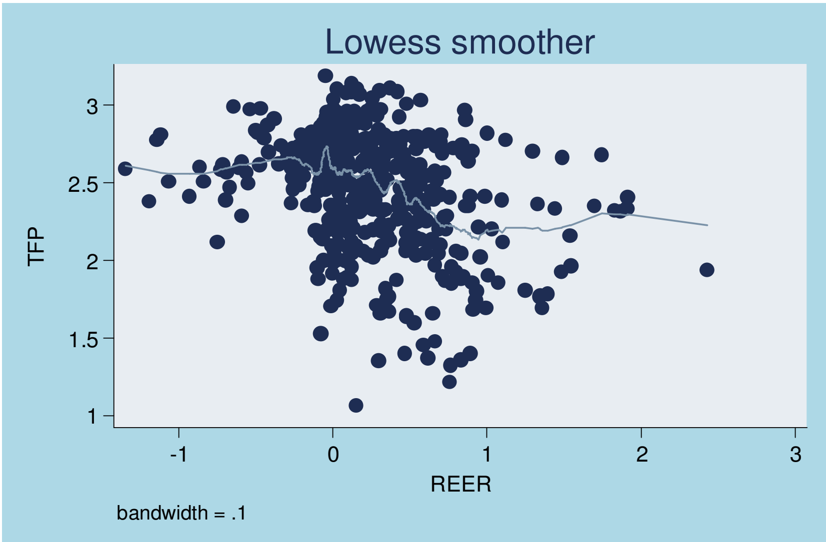



Note: The period of study is 1960-1999. Source: Source: Author's calculations.

- ***Nonparametric Estimation Between TFP and Real Effective Exchange Rate:***

To examine the possible existence of nonlinearities between the REER and the TFP, we present, in Figure 1.3, a nonparametric estimation of the Logarithm TFP on the Logarithm of the REER by the method Lowess *(Locally Weighted Scatterplot Smoothing)*. This method allocates to each point of the x-axis a value predicted by a linear regression on all neighboring points balanced according to their distance. The parameter which changes the intensity of smoothing is the percentage of points included in each regression. Smoothing is higher the percentage of points included is high. We have chosen the percentage of points included as being 10% in order to visualize the essential break points. We observe that the relationship REER-TFP is strongly nonlinear. We notice that below the approximate break point of 0.9, real exchange rate appears to acts negatively on productivity while above this threshold real exchange rate seems to have a positive effect on TFP. This result is corroborated by the econometric estimations in this chapter.

**<u>Figure 1.3:</u> Nonparametric Estimation of TFP on Real Effective Exchange Rate**



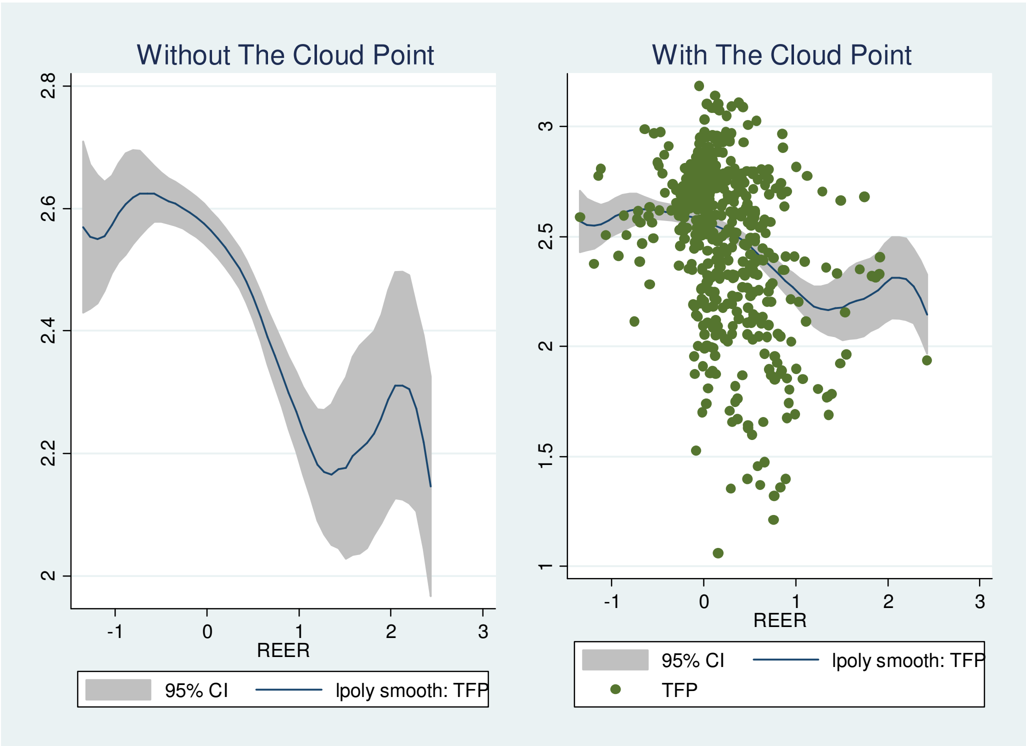

Note: These two variables are expressed in Logarithm. The Bandwith employed is 10%. The period of study is 1960-1999. Source: Author's calculations.

- ***Local Polynomial Smooth Plot Between TFP and Real Effective Exchange Rate:***

Figure 1.4 gives the local polynomial smooth plot between TFP and REER. The first graph is without the cloud point and the second with the cloud point. The gray area represents the 95% confidence interval (CI). The CIs are very small, indicating the precision of the fitting. As

Figure 1.3, we observe that, there exist a strong nonlinear relationship between TFP and REER. Below the threshold, REER seems to act negatively on TFP, while it reacts positively on TFP above the threshold. Figures 1.3 and 1.4 appear to demonstrate that the nonlinear connection between TFP and REER we found in this chapter is not fortuitous.

**Figure 1.4: Local Polynomial Smooth Plot with Confidence Interval between TFP and Real Effective Exchange Rate**




Note: These two variables are expressed in Logarithm. The period of study is 1960-1999. Source: Author's calculations.

The graphs presented in this section illustrate that the level of REER acts positively on TFP. In addition the impact of the level of the REER on TFP is nonlinear. It is therefore important to examine these correlations observed in these stylized facts more rigorously. This is what we investigate, in the remaining sections of this chapter.

## 1.5 Calculation of Total Factor Productivity

Total factor productivity is calculated from a stochastic production frontier using the method of *Battese and Coelli (1992),* on quinquennial data for all countries of the sample of study. Before going further on this method, let us explain the concept of technical inefficiency in output for a firm. We say that a firm is technically inefficient when it does not manage to position its production on its frontier production possibilities. In other words, the firm potentially produces less than what it should produce because of existence of the technical inefficiency. As explained in the General Introduction, the stochastic frontier analysis method is an econometric (parametric) frontier method and is applied to both microeconomic and macroeconomic data. Hence the concept of technical inefficiency of a firm can be applied to a country without problem. For more information on this, see the survey of *Del Gatto et al. (2011).* Also there are many studies that apply stochastic frontier techniques on macroeconomic data.

In the method of *Battese and Coelli (1992),* the technical inefficiency is modeled as a truncated normal random variable multiplied by a specific function of time. This implies that for a panel of countries we have:

$$\ln(Y_{it}) = f\left[\ln(X_{it}), \beta\right] - u_{it} + v_{it}; \;\; u_{it} \geq 0 \tag{1.1}$$

Where:

$\ln(Y_{it})$ and $\ln(X_{it})$ are respectively the logarithm of output and inputs for country $i$ at time $t$;

$u_{it} = \exp\left\{-\eta(t - T_i)\right\} u_i$ is the technical inefficiency;

$T_i$ the last period of the $i^{th}$ country;

$\eta$ is a parameter;

$u_i \overset{iid}{\sim} N^{+}(\mu, \sigma_{\mu}^{2})$ and $v_{it} \overset{iid}{\sim} N(0, \sigma_{v}^{2})$ ;

$u_i$ and $v_{it}$ are independently distributed one and the other and the regressors.

This method is used to estimate a Cobb-Douglas production function (constant returns to scale and non-constant returns to scale)[13]

$$Y_t = A_t K_t^{\alpha} L_t^{\beta}$$

By dividing the two sides by $L_t$ , we have:

$$y_t = A_t k_t^{\alpha} L_t^{\alpha + \beta - 1}$$

By taking the log of the two sides we get:

$$\ln(y_t) = \ln(A_t) + \alpha \ln(k_t) + (\alpha + \beta - 1)\ln(L_t)$$

The estimated equation can be written as:

$$\ln(y_{it}) = \beta_1 + \beta_2 \ln(k_{it}) + \beta_3 \ln(L_{it}) - u_{it} + v_{it} \tag{1.2}$$

[13] We specify here the general form without constant returns. To obtain the constant returns the equation (1.2) is estimated while imposing $\beta_3 = 0$, which correspond to $\alpha+\beta$-1=0

With $y_{it}$ output per worker, $k_{it}$ capital per worker, $L_{it}$ the number of workers, $i$ countries, $t$ time, $u_{it}$ and $v_{it}$ are as defined previously.

Total factor productivity $(TFP_{it})$ is then:

$$TFP_{it} = \exp\left\{\ln(y_{it}) - \left[\hat{\beta}_2 \ln(k_{it}) + \hat{\beta}_3 \ln(L_{it})\right]\right\} \tag{1.3}$$

The results of the estimates of the production functions that are used to calculate the total factor productivity measurements are provided in Table 1.1 in the Appendices of Chapter 1. The results illustrate that both capital per worker and the number of workers act positively on output per worker. The effect of capital per worker is highly statistically significant with a very important absolute value. By contrast, the number of workers is not statistically significant. Its magnitude is also too low. The results also show that we cannot reject the null hypothesis of constant returns to scale in this Cobb-Douglas specification. The time varying decay model is estimated. With this model, the inefficiency decreases (increases) over time towards (to) the base level according to the value of $\eta$. The last period for each country contains the base level inefficiency for that country.

Although based on stochastic frontier analysis techniques, the measurement of TFP used in this chapter is different from that of chapter 2. The measure employed in the second chapter is based on the full decomposition of TFPG according to its sources[14] while the one in the first chapter is based on the Solow residual. The quantity in chapter 2 is a growth rate while the one in this chapter is in level. Finally the measurement in chapter 2 is computed from a flexible translog production function while the one in chapter 1 is obtained from a Cobb-Douglas function. We

[14] *Kumbhakar and Lovell (2000)*

chose to use a different measure for each chapter for the need of robustness and to enrich our field of studies.

## 1.6 Econometrics models and estimations methods

In this section we successively present the generalized method of moments (GMM) estimation technique and the *Hansen (1999)* method. We choose to employ system GMM for the following main reason. The TFP variable used here is in level. To obtain total factor productivity growth we need to introduce the logarithm of the lagged value of TFP. The inclusion of this lagged dependent variable makes that we cannot utilize traditional panel data techniques like fixed effect or random effects. More explanations for why we employ the system GMM estimation method are given further below. We use the *Hansen (1999)* method because in the theoretical part we argued that real exchange rate can act both positively and negatively on total factor productivity. Thus the *Hansen (1999)* method is the perfect econometric technique since it allows taking into account the behavior of nonlinearity in the variables. As implied previously, the system GMM method is a dynamic linear panel data method while the *Hansen (1999)* is a non-dynamic nonlinear panel data estimation technique. Since we want to investigate the effect of REER on productivity both linearly and nonlinearly, these two previous estimation methods are the ideal candidates for our present study. We choose not use system GMM in chapter 2 because the measurement of productivity employed there is a growth rate.

### 1.6.1 The GMM estimation method

To estimate the impact of real exchange rate on productivity, the method of system GMM is used. The estimated equation is:

$$y_{i,t} - y_{i,t-1} = (\alpha - 1) y_{i,t-1} + \beta^{'} X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \tag{1.4}$$

Where $y_{i,t}$ is the log of total factor productivity, in this case $y_{i,t} - y_{i,t-1}$ represents total factor productivity growth. $X_{i,t}$ represents the regressors. $\mu_i$ country fixed effects. $\lambda_t$ time fixed effects. $\varepsilon_{it}$ idiosyncratic errors. $i$ indicate countries and $t$ the time.

Equation (1.4) can be equivalently rewriting as:

$$y_{i,t} = \alpha y_{i,t-1} + \beta^{'} X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \tag{1.5}$$

The standards methods of estimation cannot be used to estimate equation (1.5) because of the presence of the lagged dependent variable. Two methods are available to estimate this equation: the estimator of *Arellano and Bond (1991)* or difference GMM and the system GMM estimator.

We use the system GMM estimator because *Blundell and Bond (1997)* showed using Monte Carlo simulations that the system GMM estimator is more efficient than the difference GMM estimator. The system GMM method consists in simultaneously estimating by the method of generalized moments the following two equations:

$$y_{i,t} = \alpha y_{i,t-1} + \beta^{'} X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \tag{1.6}$$

$$y_{i,t} - y_{i,t-1} = \alpha(y_{i,t} - y_{i,t-1}) + \beta'(X_{i,t} - X_{i,t-1}) + (\lambda_t - \lambda_{t-1}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \quad (1.7)$$

Equation (1.7) is called equation of first differences and equation (1.6) equation in level. The equation in level is instrumented by the variables in first differences whereas the equation in first differences is instrumented by the lagged values of the variables in level. The instruments[15] are generated using the following moment conditions:

- *For the equation in first difference (equation 1.7)*

$$E\left[y_{i,t-s}.\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \text{ for } s \geq 2; t = 3,...,T \quad (1.8)$$

$$E\left[X_{i,t-s}.\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0, \text{ for } s \geq 2; t = 3,...,T \quad (1.9)$$

- *For the equation in level (equation 1.6)*

$$E\left[\left(y_{i,t-s} - y_{i,t-s-1}\right).\left(\mu_i + \varepsilon_{i,t}\right)\right] = 0 \text{ , for } s = 1 \quad (1.10)$$

$$E\left[\left(X_{i,t-s} - X_{i,t-s-1}\right).\left(\mu_i + \varepsilon_{i,t}\right)\right] = 0, \text{ for } s = 1 \quad (1.11)$$

The conditions (1.8) to (1.11) combined with the generalized method of moments allow estimating the coefficients of the model. We use the system GMM estimator since, first we will have the lagged dependent variable as a regressor, second the endogeneity of the link real exchange rate-productivity and third the use of macroeconomics data which are highly endogenous. Hence the System GMM in addition to account for unobserved heterogeneity of countries and omitted variables, it allows to solve the endogeneity of real exchange rate and other control variables including the measurement error on variables problem. Moreover it is

[15] To test the validity of the lagged variables as instruments, *Arellano and Bond (1991)*, *Arellano and Bover (1995), Blundell and Bond (1997)* suggest the test of over-identification of Sargan and the test of autocorrelation of second order.

more efficient than the *Arellano and Bond (1991)* and the non-dynamic panel data fixed effect estimators.

## 1.6.2 The *Hansen (1999)* estimation method

In the theoretical part, we stated that exchange rate could act positively or negatively on productivity. This suggests than the effect of real exchange rate on productivity is nonlinear. We use the *Hansen (1999)* method of determination of endogenous thresholds to test this assumption.

The estimated equation is written as

$$\begin{aligned} TFP_{it} &= \beta_1 REER_{it} I(REER_{it} \le \gamma) + \beta_2 REER_{it} I(REER_{it} > \gamma) \\ &\quad + \delta' X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned} \tag{1.12}$$

Where:

$I(\bullet)$ is an index function according to whether real effective exchange rate $(REER_{it})$ is lower or higher than the endogenous threshold $\gamma$;

$TFP_{it}$, $REER_{it}$, $X_{it}, \mu_i, \lambda_t$ and $\varepsilon_{it}$ are defined and calculated in the same way as in equation (1.4).

The method of *Hansen (1999)* consists in estimating equation (1.12) by fixed effects in two stages:

- Find the endogenous optimal threshold $\hat{\gamma}$ which minimizes the sum of squared residuals ($S_1$) of equation (1.12) estimated by fixed effects:

$$\hat{\gamma} = \underset{\gamma}{\operatorname{argmin}}\, S_1(\gamma)$$

- Test the significativity of the threshold $\hat{\gamma}$. The null assumption of the absence of threshold effect is written: $H_0: \beta_1 = \beta_2$. This assumption is tested by the statistics $F_1 = \frac{\left(S_0 - S_1(\hat{\gamma})\right)}{\hat{\sigma}^2}$ where $S_0$, $S_1$ and $\hat{\sigma}^2$ are respectively the sum of squared residuals under $H_0$, the sum of squared residuals under $H_A$ and the estimated variance of the residuals. The problem to carry out this test is that under $H_0$ he non-identification of the threshold implies that $F_1$ does not follow the standards statistical distributions. To cure it, *Hansen (1999)* proposes to carry out a bootstrap in order to derive a distribution of the statistic $F_1$. For the needs of inferences on the significativity of the endogenous threshold, he proposes to build, for all $\hat{\gamma}$ a confidence interval on the basis of the likelihood ratio according to $LR_1(\gamma) = \frac{\left(S_1(\gamma) - S_1(\hat{\gamma})\right)}{\hat{\sigma}^2}$.

# 1.7 Data and Variables

The sample of study includes 68 countries: (22) developed and (46) developing countries over the period 1960-1999[16]. It is important to note that this chapter was written in December 2005 and uses the former CERDI real effective exchange rate variable which in that time was going from 1960 to 1999. This is why the sample of study goes from 1960 to 1999. The reader might find the sample short but if we place ourselves in 2005, the sample would not be short since there was only a five year interval between the two dates. In order to eliminate cyclical fluctuations and to focus on middle and long term relationships, the averages over five years were calculated. Consequently, the temporal depth was reduced to eight sub-periods: 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, and 1995-1999. The data mainly come from *Summers and Heston (2004) (Penn World Tables 6.1), the World Bank (World Development Indicators, 2004), Barro and Lee (2000), Easterly (2001) and CERDI (2000)*.

The literature on real exchange equilibrium and real exchange rate misalignment states that some of our control variables like openness, government consumption, inflation and the terms of trade are correlated with real exchange rate. Hence the effect of real exchange rate on productivity could pass by these variables. If we estimate an equation in which we put these variables and the REER we would be estimating the direct or partial effect of REER on TFP. This effect is the one that does not pass through these intermediary variables. Since we are interested in the estimation of the total effect of REER on productivity, we regress, using System GMM, each of these control variables on real exchange rate and put the resulting residues on the main estimations of the impact of real exchange rate on productivity in tables 1.5, 1.6, 1.7, 1.8

[16] This sample size is given according to the availability of the data. Table 1.2. gives the list of countries.

and 1.9[17]. We proceed as such because these control variables are transmission channels of REER to TFP. Hence we are estimating the total effect of real exchange rate on productivity since we have taken into account the effect that real exchange rate have on these control variables. See *Sylvianne Guillaumont and Hua (2003)* for further details on these techniques.

Tables 1.3 and 1.4 respectively provide the details of calculation of all the variables and the descriptive statistics.

## 1.8 Results

In this section, we will successively presents the results in system GMM and the *Hansen (1999)* method results.

### 1.8.1 System GMM estimation results

The system GMM estimation results are presented in Table 1.5. The statistics of the test of Sargan show that we cannot reject the null assumption of validity of lagged variables as instruments. In the same way, the statistics AR(2) show that we cannot reject the null assumption of absence of autocorrelation of second order of the errors. This implies that the estimation of the relationship real exchange rate-productivity of our sample by the system GMM is applicable. All the regressions are carried out with robust standard-errors obtained by the procedure of estimation of system GMM in one stage. These standard deviations are efficient for the presence of any form of heteroskedasticity and autocorrelation in the panel.

[17] The regression results of each of these control variables on Real Exchange Rate are available upon request.

The coefficient of the real effective exchange rate is significant and has a positive sign. This means that an appreciation of the real effective exchange rate increases the productivity. The use of instrumental variables makes it possible to say that the positive relation between the real effective exchange rate and the productivity seems to go from the real effective exchange rate towards the productivity and not the reverse. The impact of real effective exchange rate on productivity is very high. While being based to regression (4), and by supposing a variation expressed in percentage of real effective exchange rate of 35%, the corresponding rise of total factor productivity is 4%.

The minus coefficient of the logarithm of lagged total factor productivity indicates a conditional convergence compared to the productivity. This convergence is conditional in what it shows a growth from the total factor productivity is higher as the former productivity is low, only if the other explanatory variables are maintained constant. The coefficient indicates that conditional convergence is very high because it is carried out at a rate of 18%.

The GDP per capita is significant at 1% and positive in all equations. The positive sign of the initial GDP per capita means that convergence compared to total factor productivity is larger as the initial GDP per capita is high.

The human capital is significant and has the expected sign in all regressions. The magnitude of the human capital coefficient is higher than that of all the other variables in all regressions. This suggests that the human capital exerts a significant positive impact on total factor productivity.

The other controls variables are only marginally significant.

### 1.8.2 The *Hansen (1999)* estimation results

The *Hansen (1999)* estimation results are presented in Table 1.6. The temporal specific effects were taken into account. The robust standard errors are between brackets. The endogenous threshold is equal to -0.2525. The real exchange rate corresponding to this threshold is equal to 0.7769. The statistics of the likelihood ratio indicates that the endogenous threshold is significant to 5%. This suggests that the effect of real exchange rate on total factor productivity is nonlinear. Under the threshold, real exchange rate acts negatively on productivity while above the threshold real exchange rate has a positive effect on productivity.

## 1.9 Robustness Analysis

Table 1.7 gives the regression according to an alternative measurement of total factor productivity. The alternative measurement is the logarithm of total factor productivity, Cobb-Douglas function with non-constant returns, method of *Battese and Coelli (1992).* The result shows that the impact of real exchange rate on total factor productivity is robust if we use an alternative measurement of total factor productivity. This means that the REER continues to act positively on TFP. The impact of REER remains very high with a magnitude slightly above that of the REER in regression 4, Table 1.5.

Table 1.8 gives the estimations on the subsamples of Developing countries and Non-Developing countries. The results illustrate that the impact of real effective exchange rate on total factor productivity is robust with the estimate on the subsamples of Developing countries and Non-Developing countries. This means that the coefficient keep the same sign as in the main regressions in Table 1.5. The absolute values of the coefficients in Table 1.8 are also comparable to those in the main estimations. The other regressors are, generally, significant and have the expected signs as in Table 1.5.

Table 1.9 provides the robustness of the estimation of the *Hansen (1999)* method to the inclusion of more control variables. The outcome demonstrates that the threshold remains the same when we introduce more regressors. The coefficients of the REER below and above the threshold are statistically significant at conventional levels. The coefficients of the other regressors are not included. Also only the important statistics are incorporated. The *F1* statistic is very close to that of Table 1.6 and the p-value of the significance of the threshold is identical in the two tables. The result found in Table 1.9 seems to corroborate the fact that the impact of REER on productivity is nonlinear.

# 1.10 Conclusion

This chapter explored the relation between the real effective exchange rate and the total factor productivity in the medium and long term. The results show that an appreciation of the real effective exchange rate increases the productivity.  This means that REER appreciation is favorable to productivity. The impact of real effective exchange rate on productivity is very high. By supposing a variation expressed in percentage rate of real effective exchange of 35%, the corresponding rise of the total factor productivity is 4%. The results also illustrates that this effects of real exchange rate on productivity is nonlinear. Under the threshold, real exchange rate acts negatively on productivity while above the threshold real exchange rate has a positive effect on productivity.

The intuition behind  these results is that when we estimate a dynamic linear panel data model, it is the positive effect of real exchange rate on productivity that seems to appear in the results. Otherwise in linear panel data the positive effect of REER on TFPG dominates the negative effect. This means that REER increase productivity by reducing the price of imported capital stock, by augmenting real remuneration of the workers and by rising the competition national firm are facing. The threshold effect estimation method on the other hand digs deeper in the results found previously and says that although the positive effect seems to dominate, there exist in fact a nonlinear link between REER and TFP. The relationship is non-monotonic and there exist a U or V type curve between the two variables. When the REER is not very high any real exchange rate appreciation seems to act badly on productivity. In this case REER harms productivity by reducing exports and openness, by hindering domestic and foreign direct investments and by causing a bad allowance of production factors. But above the threshold, the positive effect of REER found previously takes over. The economic explanation of this threshold effect is that when REER is not very high (below the threshold), agents in the economy are not familiar with REER appreciations, so any real appreciation plays badly on their economic plans. But when the REER is already large (above the threshold), agents know that they cannot be protected by a low exchange rate, hence they undertakes the necessary actions that help them improve their competiveness which in turn act positively on productivity.

From an economic policy point of view the results generally highlight that real exchange rate appreciation could augment productivity in the middle and long-run. But for countries where the REER is not much appreciated, an augmentation of this REER could harm productivity. A positive impact of REER appreciation could only happen in countries where this variable is already high.

This chapter has examined the connection between the level of REER and productivity. A natural question we might ask is what are the potential links between the associated measurements of REER and productivity? To answer to this question the next chapter studies the connection between REER volatility and TFPG.

# Appendices of Chapter 1

## Table 1.1: Results of the regressions of the production functions used for calculation of the Total Factor Productivity

| | | |
|---|---|---|
| Production Function Cobb-Douglas. *Battese et Coelli (1992)* Method | | |
| Dependent variable : ln(y) | | |
| Regressors | Non-constant returns to scale | Constant returns to scale |
| ln(k) | 0.4719*** | 0.4762*** |
| | (0.0160) | (0.0143) |
| ln(L) | 0.0092 | |
| | (0.0152) | |
| Constant | 2.8199*** | 2.8983*** |
| | (0.2626) | (0.2314) |
| Time varying decay model | yes | yes |
| Observations | 544 | 544 |
| Number of countries | 68 | 68 |
| Test of constant returns to scale | 0.5443 | |

Note: Robust standard errors are between brackets. For the test of constant returns to scale, it is the p-value that is reported. * significant at 10%; ** significant at 5%; *** significant at 1%

## Table 1.2: List of Countries

| Nº | Country codes (WB) | Country Name | Nº | Country codes (WB) | Country Name |
|---|---|---|---|---|---|
| 1 | ARG | Argentina | 35 | KEN | Kenya |
| 2 | AUS | Australia | 36 | KOR | Korea, Rep. |
| 3 | AUT | Austria | 37 | LKA | Sri Lanka |
| 4 | BEL | Belgium | 38 | LSO | Lesotho |
| 5 | BOL | Bolivia | 39 | MEX | Mexico |
| 6 | BRA | Brazil | 40 | MUS | Mauritius |
| 7 | CAN | Canada | 41 | MWI | Malawi |
| 8 | CHE | Switzerland | 42 | MYS | Malaysia |
| 9 | CHL | Chile | 43 | NER | Niger |
| 10 | CMR | Cameroon | 44 | NIC | Nicaragua |
| 11 | COL | Colombia | 45 | NLD | Netherlands |
| 12 | CRI | Costa Rica | 46 | NOR | Norway |
| 13 | CYP | Cyprus | 47 | NZL | New Zealand |
| 14 | DNK | Denmark | 48 | PAK | Pakistan |
| 15 | DOM | Dominican Republic | 49 | PAN | Panama |
| 16 | ECU | Ecuador | 50 | PER | Peru |
| 17 | EGY | Egypt, Arab Rep. | 51 | PHL | Philippines |
| 18 | ESP | Spain | 52 | PNG | Papua New Guinea |
| 19 | FIN | Finland | 53 | PRT | Portugal |
| 20 | FRA | France | 54 | PRY | Paraguay |
| 21 | GBR | United Kingdom | 55 | RWA | Rwanda |
| 22 | GHA | Ghana | 56 | SEN | Senegal |
| 23 | GMB | Gambia, The | 57 | SLV | El Salvador |
| 24 | GRC | Greece | 58 | SWE | Sweden |
| 25 | GTM | Guatemala | 59 | SYR | Syrian Arab Republic |
| 26 | HND | Honduras | 60 | TGO | Togo |
| 27 | IDN | Indonesia | 61 | THA | Thailand |
| 28 | IND | India | 62 | TTO | Trinidad and Tobago |
| 29 | IRL | Ireland | 63 | URY | Uruguay |
| 30 | IRN | Iran, Islamic Rep. | 64 | USA | United States |
| 31 | ISR | Israel | 65 | VEN | Venezuela, RB |
| 32 | ITA | Italy | 66 | ZAF | South Africa |
| 33 | JAM | Jamaica | 67 | ZAR | Congo, Dem. Rep. |
| 34 | JPN | Japan | 68 | ZWE | Zimbabwe |

# **Table 1.3:** Definitions and methods of calculation of the variables

| Variables | Definitions | Expected Sign | Sources of data |
|---|---|---|---|
| Real effective exchange rate | Weighted average of the bilateral exchange rates according to the trade partners. Base 100=1995. An increase is an appreciation. | Positive or Negative | *CERDI database (2000)* |
| Initial GDP per capita | GDP per capita (1996 constant dollars) beginning of period. | | *Penn World Table 6.1* |
| Human Capital | The human capital is calculated at the beginning of period as the sum of the average number of years of studies in the secondary of the men, the average number of years of studies in the secondary of the women, the average number of years of studies in the tertiary sector of the men and the average number of years of studies in the tertiary sector of the women balanced by their respective coefficients in a regression including the growth rate of total factor productivity, the initial GDP per capita, the residue of openness, the residue of government consumption and the residue of inflation. | Positive | *Barro et Lee (2000)* |
| Residue of openness* | Residue of the regression of the logarithm of the Openness = (Exports +Imports)/GDP on the logarithm of the real effective exchange rate. | Positive | *World Bank, World Development Indicators, 2004* |
| Residue of government consumption* | Residue of the regression of the logarithm of the Government consumption = Government Consumption /GDP on the logarithm of real effective exchange rate. | Negative | |
| Residue of inflation* | Residue of the regression of ln(1+inflation) on the logarithm of real effective exchange rate. | Negative | |
| Residue of the growth of the terms of trade* | Residue of the regression of the Growth rate of the terms of trade on the logarithm of real effective exchange rate. | Positive | *Easterly, 2001* |

Note: *This method of calculation of the controls variables is similar to that used by *Sylvianne Guillaumont and Hua, 2003*. The idea is to be able to calculate the total impact of the Real Exchange Rate on Productivity.

# <u>Table 1.4:</u> Descriptive statistics on variables

| Variables | Observations | Means | Standard deviations | Minimum | Maximum |
|---|---|---|---|---|---|
| lpgfcx* | 544 | 2.5009 | 0.3648 | 1.0606 | 3.1842 |
| lpgfnx** | 544 | 2.4233 | 0.3691 | 0.9541 | 3.1238 |
| Real effective exchange rate | 529 | 1.4153 | 0.9339 | 0.2598 | 11.3760 |
| Initial GDP per capita | 544 | 6869.9260 | 6212.5730 | 321.7051 | 28409.6200 |
| Human Capital | 541 | -0.0485 | 0.0741 | -0.3345 | 0.1327 |
| Residue of openness | 453 | 2.23E-10 | 0.1880122 | -0.8063945 | 0.8506406 |
| Residue of government consumption | 448 | 2.87E-10 | 0.1764319 | -0.8675174 | 0.8297289 |
| Residue of inflation | 455 | -2.02E-10 | 0.3107403 | -0.705259 | 3.469315 |
| Residue of the growth of the terms of trade | 439 | -6.80E-12 | 0.077388 | -0.3542168 | 0.2589573 |

Note: * lpgfcx: logarithm of Total Factor Productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992).*

** lpgfnx: logarithm of Total Factor Productivity, Cobb-Douglas function with non-constant returns, method of *Battese and Coelli (1992*

## **Table 1.5:** System GMM estimation results

Dependent variable: logarithm of Total Factor Productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992)*

| Regressors | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| ln (productivity), t-1 | -0.2251** | -0.1621* | -0.2019** | -0.1456 |
| | (0.0907) | (0.0955) | (0.0882) | (0.1052) |
| ln(Real effective exchange rate), t | 0.0869** | 0.0831* | 0.0785* | 0.1196** |
| | (0.0431) | (0.0422) | (0.0436) | (0.0513) |
| ln(Initial GDP per capita) | 0.1602*** | 0.1385*** | 0.1503*** | 0.1588*** |
| | (0.0407) | (0.0373) | (0.0405) | (0.0454) |
| Initial human capital | 0.8018** | 0.5965* | 0.6975** | 0.8925** |
| | (0.3641) | (0.3426) | (0.3175) | (0.3656) |
| Residue of openness, t | 0.1144 | | 0.1304 | 0.2034* |
| | (0.0973) | | (0.1051) | (0.1215) |
| Residue of inflation, t | -0.0380* | | -0.0171 | -0.0053 |
| | (0.0209) | | (0.0192) | (0.0207) |
| Residue of government consumption, t | 0.1564* | | | |
| | (0.0790) | | | |
| Residue of the growth of the terms of trade | | | | 0.1621 |
| | | | | (0.1305) |
| Constant | -0.7547*** | -0.7389*** | -0.7276*** | -0.9505*** |
| | (0.2328) | (0.2507) | (0.2311) | (0.2740) |
| Observations | 425 | 471 | 435 | 417 |
| Number of countries | 68 | 68 | 68 | 67 |
| Sargan test | 0.414 | 0.617 | 0.464 | 0.721 |
| AR(2) | 0.847 | 0.217 | 0.702 | 0.522 |
| Number of instruments | 43 | 28 | 38 | 43 |

Note: The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. For the test of Sargan and the test of autocorrelation of second order {AR (2)}, the probabilities are shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999). * significant at 10%; ** significant at 5%; *** significant at 1%.

## Table 1.6: *Hansen (1999)* estimation results

| | |
|---|---|
| Dependent variable: logarithm of Total Factor Productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992)* | |
| Estimated endogenous threshold (Gamma) | -0.2525[a] |
| Confidence region at 95% | (-0.4212 ; 0.5627) |
| REER below the threshold | -0.1217*** |
| | (0.0259) |
| REER above the threshold | 0.0773*** |
| | (0.0250) |
| Initial human capital | 0.1668 |
| | (0.1549) |
| ln(Initial GDP per capita) | 0.4826*** |
| | (0.0402) |
| Residue of government consumption, t | -0.0625* |
| | (0.0356) |
| Sum of Squared Errors under H0 | 1.6099 |
| Sum of Squared Errors under HA | 1.5073 |
| Test of significativity of the endogenous threshold | F1=0 |
| F1 | 21.4417 |
| p-value (simulation) | 0.034 |
| (Critical values à 10% ; 5% ; 1%) | (14.8787 ; 18.7998; 27.4565) |
| Number of simulations | 2000 |

Note: The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999).
* significant at 10%; ** significant at 5%; *** significant at 1%.
[a] The Real Exchange Rate corresponding to this threshold is (0.7769)

## Table 1.7: Robustness of the estimations according to an alternative measurement of Total Factor Productivity

| | |
|---|---|
| | Dependent Variable: logarithm of Total Factor Productivity, Cobb-Douglas function with non-constant returns, method of *Battese and Coelli (1992)*. |
| Real effective exchange rate | 0.1206** |
| | (0.0511) |
| | N = 417; S = 0.707 |
| | AR(2) = 0.528 |

Note: The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. For the test of Sargan and the test of autocorrelation of second order {AR (2)}, the probabilities are shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999). The coefficients corresponding to the other explanatory variables are not reported. These other explanatory variables are those included in the regression (4) of Table 2.5. It is: ln(Initial GDP per capita); Human capital, beginning of period; Residue openness, t; Residue inflation, t; Residue of growth rate of the terms of trade. The time specific effects also were taken into account but their coefficients are not reported.
** significant at 5%

## **Table 1.8:** Estimation on the sub-samples of Developing countries and Non-Developing countries

Dependent variable: logarithm of Total Factor Productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992)*

| Regressors | Developing countries | | | Non-Developing countries |
|---|---|---|---|---|
| | (1) | (2) | (3) | (1) |
| ln (productivity), t-1 | -0.209 | -0.2250** | -0.1405 | -0.2974 |
| | (0.1253) | (0.0956) | (0.1118) | (0.1738) |
| ln(Real effective exchange rate), t | 0.1253** | 0.0699* | 0.0800** | 0.1091* |
| | (0.0622) | (0.0412) | (0.0333) | (0.0569) |
| ln(Initial GDP per capita) | 0.2052*** | 0.1775*** | 0.1573*** | 0.0509 |
| | (0.0565) | (0.0482) | (0.0535) | (0.0557) |
| Initial human capital | 0.9040* | 0.7370* | 0.8053** | -0.1549 |
| | (0.4516) | (0.3799) | (0.3600) | (0.1958) |
| Residue of openness, t | | -0.0364 | 0.0208 | |
| | | (0.0997) | (0.0910) | |
| Residue of inflation, t | | -0.0442* | -0.0313* | |
| | | (0.0223) | (0.0186) | |
| Residue of the growth of the terms of trade | | | -0.0445 | |
| | | | (0.1701) | |
| Constant | -1.1653*** | -0.8756*** | -0.9392*** | 0.3497 |
| | (0.3680) | (0.3022) | (0.2691) | (0.5064) |
| Time specific effects | yes | yes | yes | no |
| Observations | 317 | 287 | 273 | 154 |
| Nomber of countries | 46 | 46 | 46 | 22 |
| Sargan test | 0.138 | 0.106 | 0.08 | 0 |
| AR(2) | 0.14 | 0.31 | 0.792 | 0.894 |
| Nomber of instruments | 28 | 38 | 43 | 22 |

*Note* The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. For the test of Sargan and the test of autocorrelation of second order {AR (2)}, the probabilities are shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999).
* significant at 10%; ** significant at 5%; *** significant at 1%

**Table 1.9: Robustness of the estimation of the *Hansen (1999)* method to the inclusion of more control variables**

| Dependent variable: logarithm of Total Factor Productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992)* | |
|---|---|
| Estimated endogenous threshold (Gamma) | -0.2525[a] |
| Confidence region at 95% | (-0.4212; 0.6631) |
| REER below the threshold | -0.122*** |
| | (0.0263) |
| REER above the threshold | 0.0802*** |
| | (0.0248) |
| Test of significativity of the endogenous threshold | F1=0 |
| F1 | 21.9546 |
| p-value (simulation) | 0.034 |
| Number of simulations | 2000 |

Note: The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999).
*** significant at 1%.
[a] The Real Exchange Rate corresponding to this threshold is (0.7769).
The coefficients corresponding to the other explanatory variables are not reported. These other explanatory variables are: Human Capital, Initial GDP per capita, Residue of government consumption, Residue of inflation and Residue of openness.

# Chapter 2:

# The Effects of Real Exchange Rate Volatility on Productivity Growth

# 2.1 Introduction

Traditionally, economists think that there is no link between business cycle and economic growth but since the seminal work of *Ramey and Ramey (1995)* there has been a growing interest in the study of the effects of volatility on growth. Researchers consider that volatility can have three different impacts on output growth: a positive effect, a negative effect and no effect. First, the defenders of a positive outcome argue that more volatility leads to higher precautionary saving and hence to higher economic growth. Volatility can also act positively on growth by the fact that it is associated with recessions which lead to the destruction of less productive firms and to higher Research and Development (R&D) expenditures *(Schumpeter (1939)* and, *Aghion and Saint-Paul (1998))*. Second, the negative effect of volatility on growth dates back to *Keynes (1936)* who states that investors take into account fluctuations of economic activity when calculating return on investment. Furthermore, high volatility can lead to lower investment if investment is irreversible *(Bernanke (1983)* and, *Aizenman and Marion (1993)*). Some researchers argue that, if there exists a strong relationship between recessions and the worsening of fiscal constraints, then high volatility could lead to lower growth. In fact, recessions could lead to less human capital accumulation and hence a reduction in growth. Volatility can also reduce growth by increasing the observed riskiness of investment projects which diminishes investment. Other causes of a negative impact of volatility on growth are macroeconomic instability, weak institutions and political insecurity. Third, those who believe in the no effect hypothesis argue that only real factors like technology and labor skills can affect output growth. In the empirical literature, *Ramey and Ramey (1995)* and *Norrbin and Yigit (2005)* find a negative link between volatility and growth. *Hnatkovska and Loayza (2003)* find that this negative relationship is largely due to big recessions and is aggravated in countries that are weak institutionally, poor, incapable to take countercyclical fiscal policies and financially underdeveloped. The results of *Imbs (2006)* show that volatility and growth are correlated positively across sectors, and negatively across countries. *Kormendi and MeGuire (1985),* and *Grier and Tullock (1989)* find that countries with higher volatility experience higher growth rate. *Rafferty (2005)* shows that expected volatility raises growth while unexpected volatility diminishes growth. His results also illustrate that the joined impact of expected and unexpected volatility reduces long-term growth most of the time and for many countries.

In the same line of the study of the relationship between business cycle and growth, researchers have recently considered the link between exchange rate volatility and growth in general and between exchange rate volatility and productivity in particular. For the exchange rate volatility-growth nexus, studies show that it can be both positive and negative. In the first place, exchange rate volatility acts positively on growth by allowing the use of very flexible monetary policy instruments in case of asymmetric shocks *(Friedman (1953))*. In the second place, a negative relationship can occur due to the inefficient foreign exchange markets in developing countries and to the uncertainty introduced by the volatility of the macroeconomic environment. Exchange volatility can have an ambiguous effect on growth by changing the relative costs of production *(Klein et al. (2003))*. Exchange rate instability can also have a vague impact on investment, inventories and employment by decreasing the credit available from the banking system. Exchange volatility can have a negative effect on growth by raising interest rates and increasing inflation instability. Exchange rate uncertainty can harm trade and consequently growth by increasing transaction risk *(Grier and Smallwood (2007))*. Some authors argue that, in developing countries, real exchange rate instability could have a more bad impact on growth because of low financial development and the presence of dollarization. Real exchange rate variations alter market signals and lead to an inefficient allocation of investment *(Guillaumont (1999))*. Real exchange rate variations can also acts negatively on investment by the uncertain environment it generates. In fact, an unstable economic situation created by exchange rate volatility can push economic agents to lose confidence in government policies which could damage the expected return on investment and thus reduce growth. For the empirical literature, *Drautzburg (2007)* find a significant negative impact of real exchange rate instability on growth for low-income countries while the effect for high-income countries is ambiguous. *Schnabl (2007)* also discover a negative link between exchange rate volatility and growth for a sample of 41 countries at the European Monetary Union periphery from 1994 to 2005.

In the literature, there are two papers that study the relationship between exchange rate volatility and productivity growth: *Aghion et al. (2006)* and *Benhima (2010)*. *Aghion et al. (2006)* use a panel of 83 countries from 1960 to 2000. They find that real exchange rate volatility can have a non-negligible effect on productivity growth, and the impact is function of the level of the financial development of the countries. Exchange rate volatility acts negatively on productivity growth in countries with low levels of financial development while it has no effect on countries with high levels of financial development. *Benhima (2010)* argues that the effect of exchange rate flexibility on productivity can also depend on liability dollarization. In a panel of 76 countries going from 1995 to 2004, he discovers that the negative impact of exchange rate flexibility on productivity is more pronounced in countries with high degree of dollarization.

Like these two previous studies, this chapter examines, empirically, the relationship between real exchange rate volatility and productivity growth. But it differentiates itself in the following way. Firstly, in the previous literature, productivity growth is measured as the ratio of real output per worker. Thus the variable used for productivity growth is a measurement of partial productivity. To solve this problem, we introduce a new measurement of total factor productivity growth derived from the stochastic production frontier literature *(Kumbhakar and Lovell (2000))*. Secondly, to take account the potential nonlinear effects of real exchange rate volatility on productivity growth, the previous works use an interaction of real exchange rate volatility and financial development. There is no problem with this econometric method but it only captures the nonlinearity in the variables. To solve this, we utilize the *Hansen (1999)* method of estimating thresholds effects in non-dynamic panel data. This method allows us to take account the potential existence of nonlinearity. Thirdly, we introduce two measurements of real exchange rate volatility that have not been used before. The first of these is the standard deviation of the residuals of the REER regressed on its lagged value and a tendency. The second measure is based on the Fano Factor (ratio of the variance and the mean of a random process in some time window). The results show, first, that real exchange rate volatility affects negatively productivity growth. Robustness analysis demonstrates that this outcome is corroborated by estimations using an alternative measurement of real effective exchange rate volatility and on subsamples of developed and developing countries. Moreover, for developing countries the negative effect of real effective exchange rate volatility is very large. Second, the results illustrate that the effect of real exchange rate volatility on productivity depends on the level of financial development. For very low levels of financial development, real exchange rate volatility has no effect on productivity growth. For moderately financially developed countries, real exchange rate volatility reacts negatively on productivity and for highly financially developed countries, real exchange rate volatility has no effect on productivity. The intuition behind this result is that countries that are poorly financially developed do not have the infrastructure (high capital stock, high investment, large financial connections) to make them vulnerable to REER volatility. They need to become a little large for REER volatility to play. In contrast in countries that are moderately financially developed, the financial tissue is fairly large and many firms are connected financially. Hence any REER volatility can harm the system. Finally countries that are highly financially developed have many insurance and protection mechanisms that protect them against the detrimental effects of REER volatility.

The remaining of the chapter is organized as follow. Section 2.2 deals with the stylized facts on real effective exchange rate volatility and productivity growth, section 2.3 presents the econometric models and estimations methods, section 2.4 analyzes the data and variables of interest. Section 2.5 gives the results and the last part concludes.

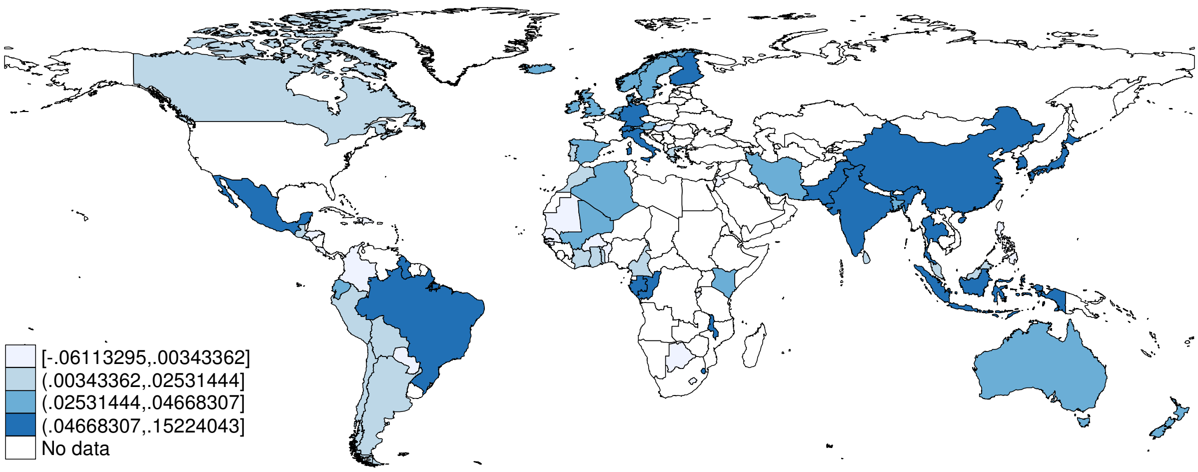
## 2.2 Stylized Facts on Real Effective Exchange Rate Volatility and Productivity Growth

In this section, we give some stylized facts on the REER and TFPG.

- ***Map of TFPG in the World for the Overall Period 1975-2004:***

Figure 2.1 provides the map of total factor productivity growth (TFPG) in the World for the entire period 1975-2004. The blue color designates the magnitude of productivity. The More the color is darker; the more productivity is high as indicated by the legend at the bottom left of the graph. This legend classifies the countries in four main categories. The figure shows that the top productive nations are: Switzerland, Germany, Finland, Italy, Japan, South Korea, Pakistan, India, China … This top group comprises many Western European economies very well known for their advanced technological progress. There are also Latin American countries and Sub-Saharan African countries in these top productive economies (Brazil, Mexico, Gabon, Malawi and Swaziland to name a few). Except some countries, this classification generally corresponds to the intuition. After this top category, the second group of productive countries is: Australia, Austria, Belgium, Bangladesh, Iran Islamic Republic, Kenya, Mali, Ecuador, etc. The third group consists of: Argentina, Bolivia, Chile, Canada, Cote d'Ivoire, Cameroon, Sri Lanka, Malaysia, Greece, Portugal … The least productive nations include: Gambia, Guinea-Bissau, Mauritania, Lesotho, Senegal, Colombia, Haiti, Paraguay, etc. This last group contains mostly African and Latin American countries well known for their lack of technological knowledge.

**Figure 2.1: Map of TFPG in the World for the overall period 1975-2004**

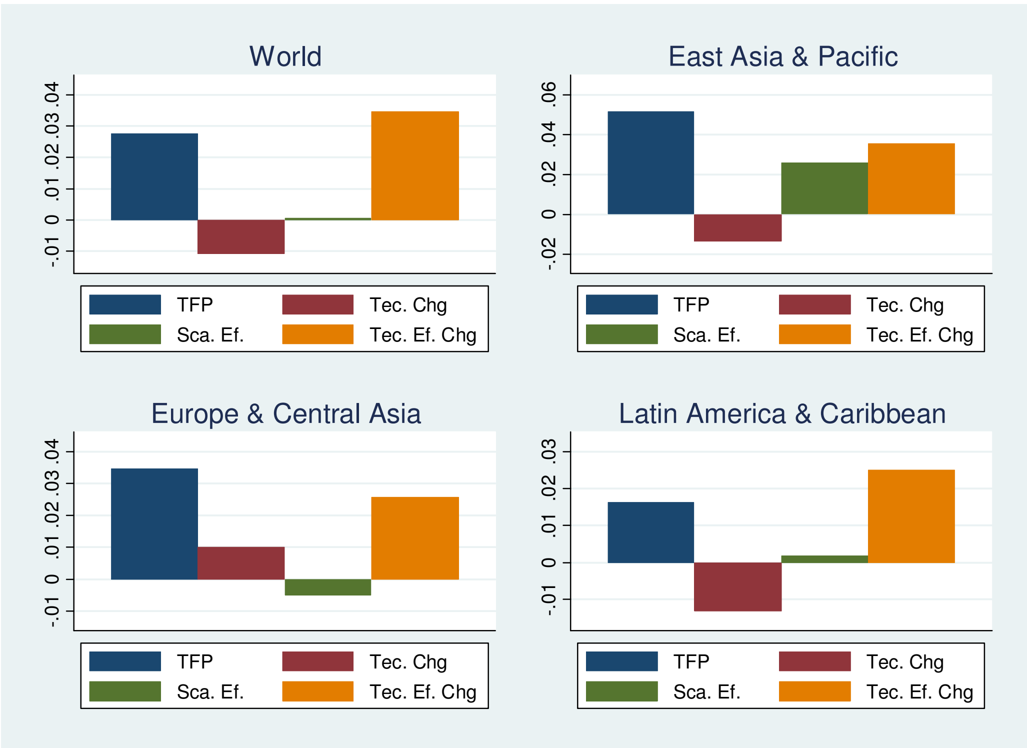



Note: The period of study is 1975-2004. Source: Author's calculations.

- ***Distribution of TFPG and its Components in the World and by Region:***

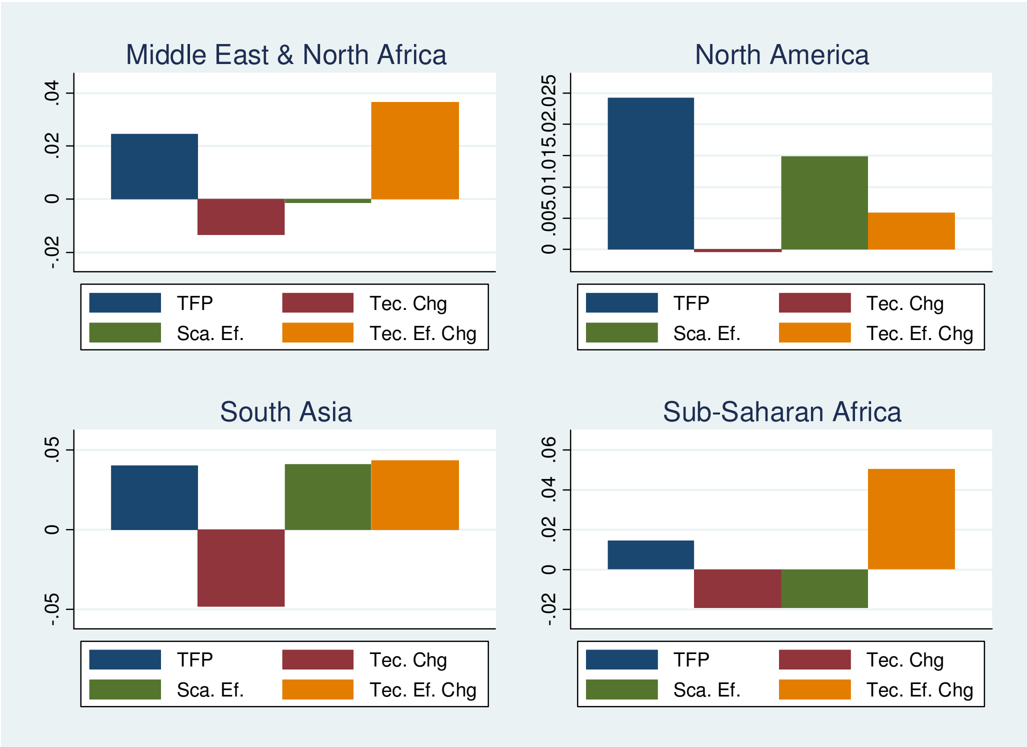
Figures 2.2 and 2.3 provide the distribution TFPG and its components (Technical Change or Technological Progress, Scale Effect and Technical Efficiency Change) in the World and by Regions for the overall period 1975-2004. TFPG in the World was fairly high due to large Technical Efficiency Change. The Scale Effect is insignificant and we notice a technological regress in the World during the overall period 1975-2004. In all regions, Technical Efficiency Change has a sizable amount. Thus the main driving force of productivity in all regions is Technical Efficiency Change. TFPG is very large in North America, Europe & Central Asia and East Asia & Pacific Regions. North America is the most productive regions with the main driving force being Scale Effect and Technical Efficiency Change. Europe & Central Asia is the most technologically advanced region with a positive value of Technical Change for the whole period 1975-2004. As for the overall World, we observe a technological regress in all other regions except Europe & Central Asia. Sub-Saharan Africa is the least productive region because of negative values of both Technical Change and Scale Effect. In many regions, beside Technical Efficiency Change, the other driving force of productivity is the Scale Effect component. Contrarily to many other empirical findings, TFPG is not negligible in East Asia & Pacific because of relatively large values of Scale Effect and Technical Efficiency Change. By opposition productivity was moderate in Latin America & Caribbean, Middle East & North Africa and South Asia. Our results are different from many other empirical finding since we employ a flexible translog production function in the context of stochastic frontier analysis. See below for more details on the computation and decomposition of TFPG.

**<u>Figure 2.2:</u> Distribution of TFPG and its Components in the World and by Region (Part 1)**




Note: The period of study is 1975-2004. Source: Author's calculations.

**Figure 2.3: Distribution of TFPG and its Components in the World and by Region (Part 2)**

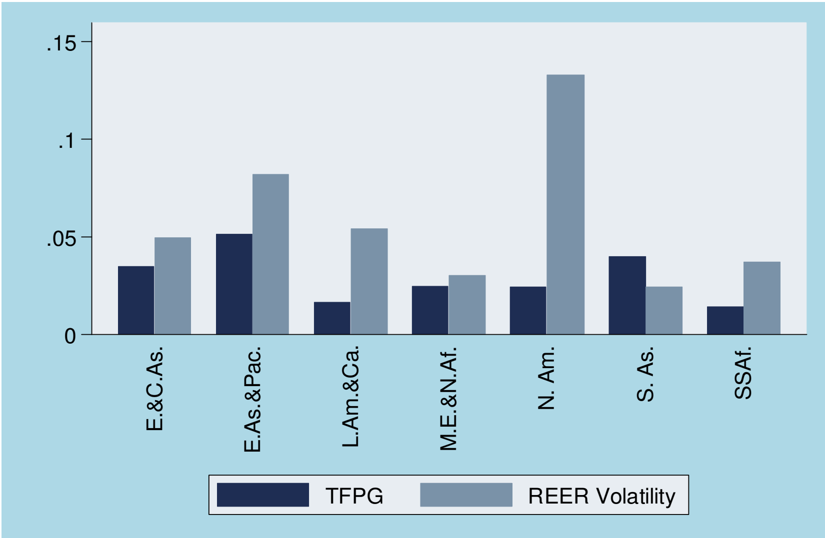



Note: The period of study is 1975-2004. Source: Author's calculations.

- ***Level of the Instability of the Real Effective Exchange Rate and TFPG by Region:***

Figure 2.4 allows us to examine the distribution of the REER volatility and productivity by region on the entire period 1975-2004. The REER volatility and TFPG are calculated according to the methods exposed in this chapter. It appears that regions with high REER volatility have lower TFPG. In contrast, South Asia, which has low volatility rates, slightly below those of Middle East & North Africa, enjoys the high productivity rates. This figure therefore demonstrates the existence of a negative correlation between REER volatility and productivity for some regions.

**Figure 2.4: The Instability of the Real Effective Exchange Rate and TFPG by Region**



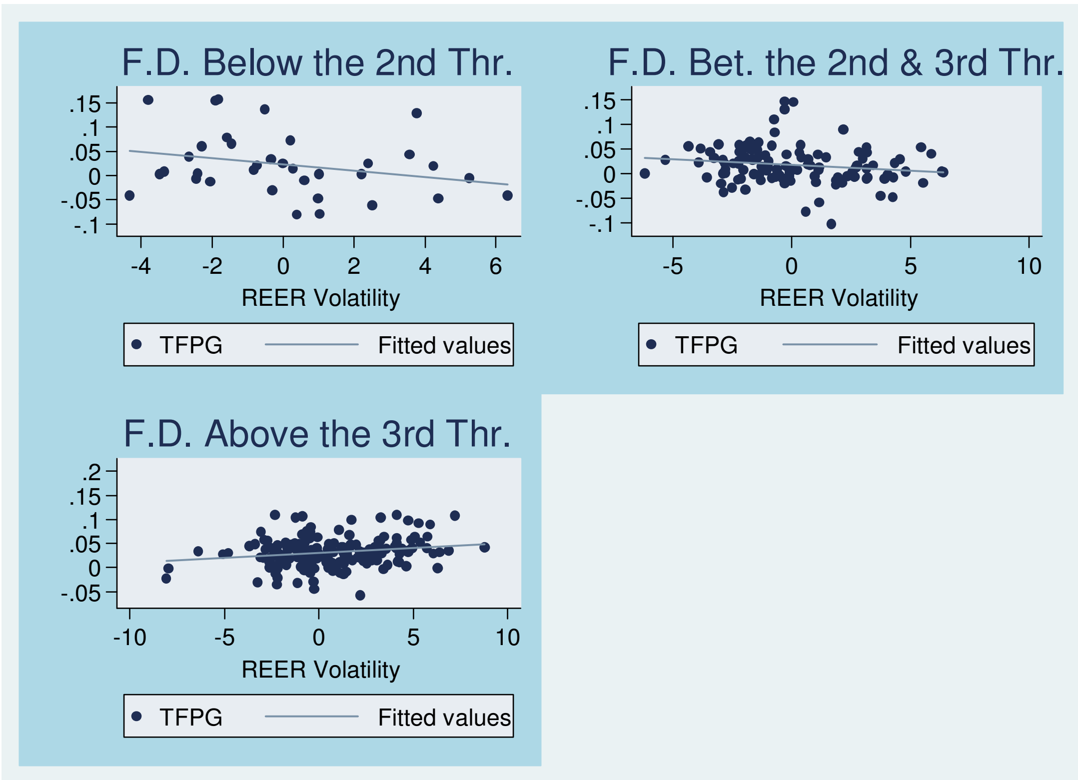

Note: The vertical bars of the figure represent the average TFPG and the logarithm of REER volatility over the period 1975-2004 for each region.

Source: Author's calculations.

- ***The TFPG in Function of the Volatility of the Real Effective Exchange Rate According to the Level of Financial Development:***

Figure 2.5 gives the relationship between the TFPG and the REER volatility according to the level of Financial Development. In this chapter, we employ the *Hansen (1999)* method of threshold effects estimation in non-dynamic panel data, to compute three thresholds in the relationship between the REER volatility and productivity according to the level of Financial Development. The first threshold is not given in Figure 2.5, since there does not exist observations between the first and the second threshold. Hence, only the second and third threshold is employed in this figure. The graph demonstrates that there is a negative correlation between the TFPG and the REER volatility for countries below the second threshold level of financial development. For countries between the second and the third threshold level of financial development, we observe a negative connection between the TFPG and the REER volatility. This link becomes positive for countries above the third threshold level of financial development. In this chapter, the econometrics results conducted here illustrate that there does not exist a first or a second threshold but there is a third threshold in all equations. These empirical results show that the association between the TFPG and REER volatility is negative below the third the threshold and positive above, but this last link is not statistically significant. Hence the outcomes presented in Figure 2.5 demonstrate, generally, what is found empirically.

**Figure 2.5: The TFPG and the Volatility of the Real Effective Exchange Rate According to the Level of Financial Development**




Note: The period of study is 1975-2004. Source: Author's calculations.

The graphs presented in this section, illustrate some key results concerning the main variables utilized in this chapter. For example REER volatility and TFPG are negatively linked. The relationship between the REER volatility and TFPG is also nonlinear according to the level of financial development. It is therefore important to examine these correlations observed in these stylized facts more thoroughly. This is what we investigate, in the remaining sections of this chapter.

## 2.3 Econometric models and estimations methods

In this section, we give a brief review of the econometric methods used to estimate the relationship between real exchange rate volatility and productivity growth.

### 2.3.1 The panel data instrumental variable estimation method

We use the panel data instrumental variable method to estimate a model of the form:

$$TFPG_{it} = \alpha REERVOL_{it} + X_{it}\beta + \mu_i + \varepsilon_{it} \qquad (2.1)$$

Where $TFPG_{it}$ is the total factor productivity growth; $REERVOL_{it}$ the logarithm of real effective exchange rate volatility; $X_{it}$ indicates the control variables utilized in the study; $\mu_i$ are the individual specific effects; $\varepsilon_{it}$ is the idiosyncratic error term; $i$ specifies countries and $t$ the time. The control variables used are: financial development, openness, human capital, government consumption, inflation, tendency of terms of trade and a crisis variable. See Table

2.1 for the definition and source of the control variables. Table 2.2 shows the summary statistics on the variables.

We use panel data instrumental variable to estimate the model in (2.1) because we suspect real exchange rate volatility to be endogenous. We think this because of the *Balassa-Samuelson* effect. This effect states that productivity affects real exchange rate. The effect supposes that productivity increases rapidly in the tradable sector than in the non-tradable sector. This causes an increase of the wages in the tradable sector. This in turn put an upward pressure on wages, particularly on the wages in the non-tradable sector. Because the prices of tradable goods are internationally determined, high wages in the non-tradable sector cause high relative price of non-tradable goods. Hence an appreciation of the real exchange rate. This theorem makes that real exchange rate volatility is endogenous. Consequently we must find instruments in order to consistently estimate the effect of real exchange rate volatility on productivity growth. Econometrics theory says that a good instrument must be uncorrelated with the error $\varepsilon_{it}$ and correlated with the real exchange rate volatility. Thus variations in the instruments are related with variations in real exchange rate volatility but do not cause variations in productivity growth, excluding indirectly through real exchange rate volatility. From the literature on the determinants of real exchange rate volatility, *Caporale et al. 2009* identifies the following variables: lagged real exchange rate volatility, volatility of terms of trade, volatility of real GDP, volatility of public expenditure, volatility of money supply, openness, FDI and portfolio investments, total liabilities and assets relative to GDP, Net Foreign Assets, and exchange rate regime. Except for lagged real exchange rate volatility, these variables cited previously are also, one way or the other, identified in the literature as determinants of productivity or real GDP per capita growth.

Hence these variables do not strictly satisfy the properties of good instruments for our present study. That is why we use only lagged real exchange rate volatility as instrument.

## 2.3.2 The threshold effect estimation method

*Aghion et al. (2006)* and *Benhima (2010)* theoretically show that the effects of REER volatility on productivity are nonlinear. *Benhima (2010)* demonstrates that the influence of exchange rate flexibility on productivity can depend on liability dollarization. He shows that the negative impact of exchange rate flexibility on productivity is more pronounced in countries with high degree of dollarization. *Aghion et al. (2006)* make evident that exchange rate volatility acts negatively on productivity growth in countries with low levels of financial development while it has no effect on countries with high levels of financial development. This is why we use the *Hansen (1999)* method of thresholds estimation in non-dynamic panels to test for the potential nonlinear effects of REER volatility on productivity.

As explained previously, we utilize the *Hansen (1999)* method of finding thresholds effects in non-dynamic panel data to estimate an equation having the following form:

$$TFPG_{it} = \alpha_1 REERVOL_{it} I(FD_{it} \leq \gamma) + \alpha_2 REERVOL_{it} I(FD_{it} > \gamma) + X_{it}\beta + \mu_i + \varepsilon_{it} \quad (2.2)$$

Where $I(\cdot)$ is the indicator function; $FD_{it}$ is the financial development variable (ratio of domestic credit to private sector to GDP); $\gamma$ is the threshold level; $\alpha_1$ and $\alpha_2$ are the marginal effects of real exchange rate volatility which can be different according to the threshold level; all other variables are defined the same way as in equation (2.1). We test the null hypothesis of linearity of real exchange rate volatility $\left(H_0 : \alpha_1 = \alpha_2\right)$ against the alternative hypothesis $\left(H_a : \alpha_1 \neq \alpha_2\right)$. The *Hansen (1999)* method consists of estimating equation (2.2) for different values of the threshold level $\gamma$. We retain the value of $\gamma$ that minimize the sum of squared residuals:

$$\hat{\gamma} = \arg\min_{\gamma} S_1(\gamma) \tag{2.3}$$

With $S_1(\gamma) = \hat{\varepsilon}(\gamma)^{'}\hat{\varepsilon}(\gamma)$ is the sum of squared residuals under $H_a$; $\hat{\varepsilon}(\gamma)$ are the estimated residuals. Next we test for the statistical significance of the threshold level. To do this, *Hansen (1999)* proposes a likelihood ratio test that allows comparing the models with and without break:

$$F_1 = \frac{S_0 - S_1(\hat{\gamma})}{\hat{\sigma}^2} \tag{2.4}$$

Where $S_0$ is the sum of squared residuals under $H_0$; $S_1(\hat{\gamma})$ is the sum of squared residuals under $H_a$ at the estimated threshold level $\hat{\gamma}$; $\hat{\sigma}^2$ is the variance of the residuals in the model without break ( $\hat{\sigma}^2 = \frac{1}{n(T-1)} S_1(\hat{\gamma})$ ). *Hansen (1999)* argues that the distribution of the statistic $F_1$ is non-standard and strictly dominates that of the chi-squared distribution with $k$ degrees of freedom. Hence critical values of this statistic cannot be obtained. To solve this, he suggests a bootstrap procedure to recover the p-value of $F_1$. *Hansen (1999)* also proposes to build a confidence interval for the estimated threshold level. He gives the following likelihood ratio:

$$LR_1(\gamma) = \frac{S_1(\gamma) - S_1(\hat{\gamma})}{\hat{\sigma}^2} \tag{2.5}$$

It is important to note that at $\gamma = \hat{\gamma}$ we have $LR_1(\hat{\gamma}) = 0$ and as he pointed out that $LR_1(\gamma)$ is different from $F_1$. *Hansen (1999)* demonstrates that the statistic $LR_1(\gamma)$ tends toward the random variable $\xi$ having the following distribution $P(\xi \le x) = \left(1 - \exp\left(-\frac{x}{2}\right)\right)^2$. By inverting this distribution, we find the following function $c(\alpha) = -2\log\left(1 - \sqrt{1-\alpha}\right)$. This function allows calculating the confidence interval for $\hat{\gamma}$. For a critical value of $\alpha\%$, the confidence interval corresponds to the values for which we have $LR_1(\gamma) \le c(\alpha)$. He shows that this confidence interval is easy to find graphically by first plotting $LR_1(\gamma)$ against $\gamma$ and second drawing a horizontal line at $c(\alpha)$. Hence the confidence interval corresponds to the values of $LR_1(\gamma)$ that are below the horizontal line and $\hat{\gamma}$ is where the curve of $LR_1(\gamma)$ touches the x-axis.

In this study we use a triple threshold model. This means that we can rewrite equation (2.2) as:

$$\begin{aligned} TFPG_{it} &= \alpha_1 REERVOL_{it} I(FD_{it} \le \gamma_1) + \alpha_2 REERVOL_{it} I(\gamma_1 < FD_{it} \le \gamma_2) \\ &+ \alpha_3 REERVOL_{it} I(\gamma_2 < FD_{it} \le \gamma_3) + \alpha_4 REERVOL_{it} I(\gamma_3 < FD_{it}) \\ &+ X_{it}\beta + \mu_i + \varepsilon_{it} \end{aligned} \tag{2.6}$$

Where the thresholds are ordered, hence $\gamma_1 < \gamma_2 < \gamma_3$. The inference for equation (2.6) follows the same reasoning as before but by taking into account the presence of threshold at each step. For more details on this, please see *Hansen (1999)*. It is important to note that *Hansen (1999)* discusses in detail the double threshold model but he argued that his reasoning could be easily extended to more than two thresholds models. His program, which we use in this study, allows for the case of triple threshold. Hence all the statistical tests (test for the statistical significance of the threshold levels, bootstrap procedure to recover the p-value of the F statistics, etc.) discussed previously apply naturally well in the case of the triple threshold model. We choose the triple threshold model because we want to let the data speak about the central question of nonlinearity. We want to stay in the tradition of nonparametric regressions. As is well known these techniques impose little restrictions on the estimations. We wish to respect this same token in our econometric regressions. To sum up we expect our estimations to be as flexible as possible.

## 2.4 Data and variables of interest

In this section, we present the data used in the study and show how the variables of interest are calculated.

### 2.4.1 Data used in the study

The sample of study contains 74 countries: (24) developed and (50) developing countries over the period 1975-2004. The choice of the sample is based on the availability of data, the choice of the variables of the study and because we want to investigate both developed and developing countries. To get rid of cyclical fluctuations and focus on middle and long term relations, the averages over five years were calculated. Therefore, the temporal depth was reduced to six non-overlapping sub-periods: 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, and 2000-2004. This method of averaging over sub-periods is frequently used in the empirical growth literature. The data essentially come from the World Bank (World Development Indicators, 2006), *Barro and Lee (2010)*, International Financial Statistics (IFS), April 2006, Centre D'études Et De Recherches Sur Le Développement International (CERDI) 2006, *Caprio and Klingebiel (2003)*, and *Kaminski and Reinhart (1999)*. Table 2.2 shows the descriptive statistics on all the variables including financial development. These statistics illustrate that all the variables are within acceptable ranges and the numbers of observations of these variables are generally in the same order of magnitude. We could also give these statistics by income groups but since many studies in the economic growth literature and in other fields of economics do not proceed as such we have chosen not list the statistics by income categories[18].

The crises variable represents financial and banking crises. These crises constitute a condition in which the assets of a country and the market capitalization of financial institutions fall quickly. These crises are characterized by circumstances in which stockholders and/or people sell their assets or take money from their banking accounts by fearing the collapse of financial institutions. If the government does not intervene, these crises can become an economic crisis in which the output fall drastically and the economy enter into a depression or a contraction.

It is important to note that the numbers of observations of the crises and TFPG variables are low compared to the other variables. The crises variable has few observations since currency and banking crises, as it is well known, occur in sporadic manner and only in some countries at a time. The total factor productivity growth variable has few values compared to the others because it has a missing value at the beginning period for each country. This is because the calculation of this variable includes the scale effect whose calculation in turn comprises the growth rate of each factor. The measurement of the growth rate of each factor makes that the value at the beginning period for each country is lost. But as we mentioned above the numbers of observations of all the variables used in the study are generally in the same order of magnitude

[18] But these statistics are available upon request.

since the spread between the lowest at the highest number of observations is only 84 observations. Hence our sample is not biased statistically speaking. Table 2.3 gives the list of all countries used in the study.

The real effective exchange rate (REER) is calculated according to the following formula:

$$REER_{ij} = \prod_{j=1}^{10} \left( NBER_{ij} \frac{CPI_i}{CPI_j} \right)^{\omega j} \tag{2.7}$$

Where:

$NBER_{ij}$: is the nominal bilateral exchange rate of trade partner $j$ relative to country $i$.

$NBER_{ij} = \frac{e_j}{e_i}$, with $e_j$ is the nominal bilateral exchange rate of partner $j$ compared to the dollar, in foreign-currency (number of dollars for a unit of domestic currency). This series is mainly from the IFS series **rf**; $e_i$ is the nominal bilateral exchange rate of the country $i$ against the dollar in foreign-currency terms (this series is mainly from the IFS series **rf**);

$CPI_i$: represents the consumer price index of country $i$ (IFS line 64). When the country $CPI$ is missing, the growth rate of the GDP deflator is used to feel the gap;

$CPI_j$: corresponds to the consumer price index of trade partner $j$ (IFS line 64). When the country $CPI$ is missing, the growth rate of the GDP deflator is used to feel the gap;

$\omega_j$: stands for trade partner $j$ weight (mean 1999-2003, PCTAS-SITC-Rev.3). Only the first ten partners are taking (CERDI method). These first ten partners constitute approximately 70% of the trade weights. The weights used to generate the REER are $\dfrac{\dfrac{\text{Exports}_j + \text{Imports}_j}{2}}{\sum_{j=1}^{10} \dfrac{\text{Exports}_j + \text{Imports}_j}{2}}$ excluding oil countries. Weights are computed at the end of the period of study in order to focus on the competitiveness of the most recent years.

The REER is computed in foreign-currency terms meaning that an increase of the REER indicates an appreciation and, hence a potential loss of competitiveness if this rise is not determined by an identical augmentation of the equilibrium REER.

The financial development variable is log of domestic credit to private sector over GDP. Domestic credit to private sector represents financial funds given to the private sector: loans, trade credits, acquisitions of not stockholders' equity securities, etc. For certain countries this variable comprise credits to public firms. We choose to use this variable since it fills the definition of financial development to a large extent and for its use in many studies on the link between financial development and economic growth.

Table 2.10 shows the correlations between all the variables used in the study. We observe that total factor productivity growth (TFPG) and the two measurements of REER volatility[19] are positively related but the correlations are insignificant. This result might the consequence of the fact that the correlations do not takes into account the effects of the other variables. The two measurements of REER volatility are positively linked and statistically significant. This reinforces our view that both of them are good measures of REER volatility. Financial development and human capital are positively associated with TFPG. Meaning that countries that have large financial development and highly trained people experience great TFPG. We also see

[19] See further below for how TFPG and REER volatility variables are measured.

that countries that are more open know little REER volatility. Additionally, countries with large inflation are financially underdeloped and less opened. Finally, financial and banking crises are more likely to happen in countries that are less opened and have little government consumption.

## 2.4.2 Measurement of variables of interest

In this subsection we illustrate how the total factor productivity growth and real exchange rate volatility are measured.

### 2.4.2.1 The calculation of Total Factor Productivity Growth

As pointed in the general introduction, this thesis is the first to introduce a measure of total factor productivity exploiting the stochastic nature of the economy. All previous works suppose that the economy progresses in a deterministic environment. In chapters 1 and 2, we employ stochastic frontier analysis methods to calculate measurements of total factor productivity. As demonstrated by the rational expectations hypothesis and the dynamic stochastic general equilibrium literature in general, economies in the real world are subject to random shocks. Hence using stochastic frontier methods is a best way of accounting for randomness in the economy.

We use the primal approach of decomposition of productivity developed by *Kumbhakar and Lovell (2000)*. The stochastic production function can be writing as follows:

$$y_{it} = f\left(x_{it}, t; \beta\right) \cdot \exp\left(-u_{it}\right) \cdot \exp\left(v_{it}\right) \qquad (2.8)$$

Where $y_{it}$ is the output; $f\left(x_{it},t;\beta\right)$ is the deterministic core of the stochastic production frontier; $\beta$ are the parameters to be estimated; $x_{it}$ represents inputs (the inputs here are capital $K_{it}$ and labour $L_{it}$); $\exp\left(-u_{it}\right)$ is the technical efficiency; $v_{it}$ is the stochastic error term; $t$ indicates time and $i$ indexes the countries. If technical inefficiency $u_{it} \geq 0$, then technical efficiency, $\exp\left(-u_{it}\right)$, lies in the range $(0,1]$. By dropping the error term from equation (2.8), the deterministic production function can be writing as:

$$y_{it} = f\left(x_{it},t;\beta\right)\cdot\exp\left(-u_{it}\right) \tag{2.9}$$

If we first take the natural logarithm of (2.9) and then differentiate with respect to time $t$, we obtain:

$$\frac{\partial \ln y_{it}}{\partial t} = \frac{\partial \ln f(x_{it},t;\beta)}{\partial t} + \sum_{j=1}^{2} \frac{\partial \ln f(x_{it},t;\beta)}{\partial \ln x_{itj}} \frac{\partial \ln x_{itj}}{\partial t} + \frac{\partial \ln \exp\left(-u_{it}\right)}{\partial t} \tag{2.10}$$

With $\overset{\bullet}{y}_{it} = \frac{\partial \ln y_{it}}{\partial t}$ is the growth rate of output; $T\Delta_{it} = \frac{\partial \ln f(x_{it},t;\beta)}{\partial t}$ is the rate of technical change; $\alpha_{itj} = \frac{\partial \ln f(x_{it},t;\beta)}{\partial \ln x_{itj}}$ is the output elasticity of factor $j$; $\overset{\bullet}{x}_{itj} = \frac{\partial \ln x_{itj}}{\partial t}$ is the growth rate of input $j$ and $TE\Delta_{it} = \frac{\partial \ln \exp\left(-u_{it}\right)}{\partial t} = -\frac{\partial u_{it}}{\partial t}$ is the rate of change in technical efficiency. With these notations, we can rewrite equation (2.10) as:

$$\overset{\bullet}{y}_{it} = T\Delta_{it} + \sum_{j=1}^{2} \alpha_{itj} \overset{\bullet}{x}_{itj} + TE\Delta_{it} \tag{2.11}$$

The growth rate of total factor productivity ($TFPG_{it} = \dot{TFP}_{it}$) is defined according to the following Divisia index:

$$TFPG_{it} = \dot{TFP}_{it} = \dot{y}_{it} - \dot{x}_{it} = \dot{y}_{it} - \sum_{j=1}^{2} s_{itj}\, \dot{x}_{itj} \qquad (2.12)$$

Where a dot over a variable designates the growth rate of that variable; $s_{itj} = \dfrac{w_{itj}x_{itj}}{\sum_{j=1}^{2} w_{itj}x_{itj}}$ is the input share of factor $j$ to total expenditure in country $i$ at time $t$; $w_{itj}$ is the price of factor $j$ in country $i$ at time $t$. Inserting equation (2.11) into equation (2.12) and after some algebra, we get:

$$TFPG_{it} = T\Delta_{it} + \left(RTS_{it} - 1\right)\sum_{j=1}^{2} \lambda_{itj}\, \dot{x}_{itj} + TE\Delta_{it} + \sum_{j=1}^{2}\left(\lambda_{itj} - s_{itj}\right)\dot{x}_{itj} \qquad (2.13)$$

Where $RTS_{it} = \sum_{j=1}^{2} \alpha_{itj}$ is the return to scale and $\lambda_{itj} = \dfrac{\alpha_{itj}}{RTS_{it}}$ represents the optimal marginal output share of factor $j$. Equation (2.13) illustrates that the total factor productivity growth is a sum of four terms: technical change $T\Delta_{it}$, scale effect $\left(RTS_{it} - 1\right)\sum_{j=1}^{2} \lambda_{itj}\, \dot{x}_{itj}$, technical efficiency change $TE\Delta_{it}$ and allocative inefficiency $\sum_{j=1}^{2}\left(\lambda_{itj} - s_{itj}\right)\dot{x}_{itj}$. As pointed out by *Kumbhakar and Lovell (2000)*, if price information is not available, the allocative inefficiency term cannot be computed. In this case, total factor productivity growth simplifies to:

$$TFPG_{it} = T\Delta_{it} + \left(RTS_{it} - 1\right)\sum_{j=1}^{2}\lambda_{itj}\,\dot{x}_{itj} + TE\Delta_{it} \tag{2.14}$$

The measurement of total factor productivity growth we use in this study is based on equation (2.14) since we do not have price information on capital and labor for all countries of our sample. *Pires and Garcia (2004)* undertake the same decomposition of productivity growth as above. But they had price information of factors only for 36 countries out of 75 and for a time period spanning from 1970-2000. This shows that if we take account the allocative inefficiency in our study, our sample would be very small both in the number of countries and in the time period. In order to obtain the different values of the productivity components derived in equation (2.14), we estimate the following flexible translog production function:

$$\begin{aligned} \ln y_{it} = \beta_0 + \beta_t t + \frac{1}{2}\beta_{tt}t^2 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \frac{1}{2}\beta_{KK}\left(\ln K_{it}\right)^2 + \frac{1}{2}\beta_{LL}\left(\ln L_{it}\right)^2 \\ + \beta_{KL}\ln K_{it}\ln L_{it} + \beta_{tK} t \ln K_{it} + \beta_{tL} t \ln L_{it} - u_{it} + v_{it} \end{aligned} \tag{2.15}$$

Where all variables are as defined previously. Technical inefficiency is calculated according to the *Battese and Coelli (1992)* specification:

$$u_{it} = \exp\left\{-\eta\left(t - T_i\right)\right\}u_i \tag{2.16}$$

Where $T_i$ is the last period in the *ith* panel; $\eta$ is the decay parameter; $u_i \overset{iid}{\sim} N^{+}\left(\mu, \sigma_u^2\right)$; $v_{it} \overset{iid}{\sim} N\left(0, \sigma_v^2\right)$; in the model, $u_i$ and $v_{it}$ are distributed independently of each other and the covariates. The parameters $\beta$, $\mu$, $\eta$, $\sigma_v^2$, $\sigma_u^2$, $\sigma_S^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \dfrac{\sigma_u^2}{\sigma_S^2}$ are estimated by maximum likelihood. Since $\gamma$ must between 0 and 1, the optimization is done in terms of the inverse logit of $\gamma$. Then the components of total factor productivity growth can be calculated as follows:

- The technical change

$$\hat{T}\Delta_{it} = \hat{\beta}_t + \hat{\beta}_{tt}t + \hat{\beta}_{tK} \ln K_{it} + \hat{\beta}_{tL} \ln L_{it} \tag{2.17}$$

- The scale component

  The output elasticity of capital, with some abuse of notation, is

$$\hat{\alpha}_{itK} = \hat{\beta}_K + \hat{\beta}_{KK} \ln K_{it} + \hat{\beta}_{KL} \ln L_{it} + \hat{\beta}_{tK}t \tag{2.18}$$

  The output elasticity of labor, with some abuse of notation, is

$$\hat{\alpha}_{itL} = \hat{\beta}_L + \hat{\beta}_{LL} \ln L_{it} + \hat{\beta}_{KL} \ln K_{it} + \hat{\beta}_{tL}t \tag{2.19}$$

  Then the return to scale is the sum of $\hat{\alpha}_{itK}$ and $\hat{\alpha}_{itL}$. Also we can get $\lambda_{itj}$ and finally calculate the scale component of productivity from these values.

- The technical efficiency change

$$T\hat{E}\Delta_{it} = \hat{\eta}\exp\left\{-\hat{\eta}\left(t - T_i\right)\right\}\hat{u}_i = \hat{\eta}\hat{u}_{it} \tag{2.20}$$

With these obtained values we can compute total factor productivity growth as in equation (2.14).

Now let's explain how each variable in equation (2.15) is calculated. The variable $y_{it}$ is real GDP corrected for purchasing power parity (PPP) in constant 2000 international \$, from the

World Development Indicators 2006. The capital stock is computed by the perpetual-inventory method according to the following formula[20]:

$$K_{it+1} = I_{it} + (1-\delta)K_{it} \tag{2.21}$$

Where $K_{it}$ is capital stock; $I_{it}$ is investment and $\delta = 0.05$ is the depreciation rate. Investment is measured as gross capital formation in constant 2000 US$ from the World Development Indicators 2006. Labour $L_{it}$ is measured as population per equivalent adult according to the following formula:

$$L_{it} = Population(0-14)*0.5 + \{Population(15-64) + Population(\geq 65)\}*1 \tag{2.22}$$

Where $Population(0-14)$ is population between 0 and 14 years; $Population(15-64)$ population between 15 and 64 years and $Population(\geq 65)$ is population from 65 years and above. The data for these variables are from the World Development Indicators (WDI) 2006. We could obtain labour from the Penn World Tables using the variable Real GDP per worker (*rgdpwok*). We did not proceed like this for two reasons: first, there are lots of missing values in this variable for our sample and second, a thorough analysis of this variable suggests that population per equivalent adult is more reliable, especially for developing countries where there are many children work and large informal sector. This means that in these countries, people would start working at early years and continue working after the official retirement age. Also the presence of informal sector implies that many workers are not recorded in the official statistics concerning the labor force. Population per equivalent adult was also used by *Pires and*

[20] For the interested reader, I introduce a new Stata User-Written command named **"stockcapit"** that computes capital stock according to this formula. The command is downloadable at: **http://ideas.repec.org/c/boc/bocode/s457270.html**
Please, see this website and the end of the thesis for the code of this command.

*Garcia (2004)* in their study but they obtained it from a transformation from the Penn World Tables instead of the World Development Indicators.

Table 2.4 presents the maximum likelihood estimates of the translog stochastic production function given in equation (2.15). The majority of the coefficients $\beta$ are significant at conventional levels. The Wald test shows that the Cobb Douglas function is rejected as the suitable representation of the data. We conducted a Wald test instead of a likelihood ratio test for the Cobb Douglas specification because we could not obtain the estimates for this restriction in order to perform the likelihood ratio test. The coefficient of the interaction between capital and labor is negative indicating the existence of substitution effect between the two production factors. The coefficient of squared time is positive indicating that the second part of the neutral part of technological progress has a positive effect on output. The signs of the interaction of capital and time, on the one hand, and labor and time, on the other hand, illustrate that the non-neutral part of technological progress increases with capital and decreases with labor. The coefficient of capital is not significant but that of capital squared is positive and significant, meaning that very high levels of capital have a positive effect on output. The coefficient of labor and labor squared are respectively negative and positive. This suggests that at low levels, labor reduces output but very high levels of labor augment output. The inverse logit of $\gamma$ is highly statistically significant and the value of $\gamma$ is very close to 1. This means that a great part of the disturbance term is due to the existence of technical inefficiency. The estimated value of $\eta$ is positive and significant, suggesting that the degree of inefficiency decreases over time toward the base level. The last period for each country $i$ contains the base level of technical inefficiency. The estimated parameters in Table 2.4 allow us to carry out the decomposition of total factor productivity growth according to equation (2.14).

### 2.4.2.2 The measurement of Real Effective Exchange Rate Volatility

We calculate two measurements of REER volatility. We employ two measures for robustness purposes. As indicated above these two variables have not been used before. The advantage of the first variable (REER volatility according to *Combes et al. (1999))* is that it is computed relative to a tendency and an autoregressive process whereas the standard deviation used in previous studies is obtained comparatively to a fixed mean (i.e. a flat value) in the corresponding time window. The second measurement of REER volatility (Fano factor) is calculated relative to a fixed mean but has the advantage to be expressed in the same unit as the original variable for which it is computed. These two measures of REER volatility are calculated on annual data for each country on a time window of five year interval. This way of proceeding allow to capture the volatility of the REER in the middle and long-term time period as is done by many studies in the economic growth literature.

As pointed previously, we compute two measurements of real effective exchange rate volatility. The first measurement is calculated according to *Combes et al. (1999)*. We start by estimating the following equation for each country $i$:

$$\ln REER_t = a + bt + c \ln REER_{t-1} + \varepsilon_t \tag{2.23}$$

Where $\ln REER$ and $\ln REER_{t-1}$ are respectively the logarithm of real effective exchange rate at time $t$ and time $t-1$; $t$ is the time trend and $\varepsilon_t$ is the error term. We compute the predicted value $\ln RE\hat{E}R_t$ from equation (2.23), take the exponential of this value and derive the real effective exchange rate volatility as the square root of the variance of the regression model's disturbances for each country and period[21]. The disturbances are measured as the difference

[21] Recall that we have six non-overlapping sub-periods: 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, and 2000-2004.

between $REER_t$ and $RE\hat{E}R_t$. In the results this first measurement of real effective exchange rate volatility is referred to as REER volatility 1. Note that this variable enters in logarithmic form in the regressions.

The second measurement of real exchange rate instability is calculated as the Fano factor named after the physicist *Ugo Fano* who invented it *((Fano (1947))*. It is defined as:

$$F = \frac{\sigma_W^2}{\mu_W} \tag{2.24}$$

Where $\sigma_W^2$ is the variance and $\mu_W$ is the mean of a random process in some time window $W$. The time window for our study is defined by the six non-overlapping sub-periods. We compute this Fano factor for the real effective exchange rate variable for each country at each sub-period. It is important to note that the Fano factor is similar to variance-to-mean ratio or index of dispersion when the time window is large or is going to infinity. The index of dispersion like the coefficient of variation is a normalized measure of the dispersion of a probability distribution. In the results this second measurement of real effective exchange rate volatility is referred to as REER volatility 2. Note that this variable enters in logarithmic form in the estimations.

## 2.5 Results

In this section, we will respectively present the results of the panel data instrumental variable estimation and those of the threshold effect estimation.

### 2.5.1 Panel data instrumental variable estimation results

All eight equations in Table 2.5 show that real effective exchange rate volatility is statistically significant at conventional levels and have the expected sign. Except equation (1) and (4), we observe that the effect of REER volatility is not too high. Referring to regression (7), an increase in REER volatility by 100% reduces total factor productivity growth just by an amount equivalent to 0.362 percentage points. These results of the existence of a negative effect between REER volatility and productivity growth corroborate those found by *Aghion et al. 2006*. The absolute value of the REER volatility coefficient in equations (1) and (4) diminishes drastically when we control for both human capital and financial development in regressions (2) and (3), and from estimations (5) to (8). This suggests that the effect of REER volatility on total factor productivity growth may pass through these last two variables. We observe that the standard errors of the coefficients of REER volatility are very small. This implies that the corresponding confidence intervals, though not reported, are tinier meaning that the coefficients of REER volatility are estimated with great precision. The use of instrumental variables in the estimations makes it possible to say that the negative relation between REER volatility and total factor productivity growth seems to go from REER volatility towards productivity growth and not the reverse. The F-test for the joint significance of all the coefficients is fairly high and significant in all equations. The overall R-squared is very low in equations (1) and (4) but becomes large when we introduce human capital and financial development[22]. The number of observations largely decreases when we introduce the crises variable but remains in reasonable proportions in the other estimations.

[22] These R-squared are comparable to the values found in many panel data studies at the international level.

The results also highlight that total factor productivity growth is strongly positively influenced by human capital and financial development. But the effect of human capital is more marked than that of financial development. The other variables have the expected signs but are statistically insignificant.

The results in Table 2.6 illustrates that REER volatility affects negatively total factor productivity growth in developed countries. As in the main estimations, we observe that the effect of REER volatility is very small. Also the standard errors of REER volatility are small. But, contrarily to the main results, the coefficient of REER volatility remains stable after we introduce financial development, human capital and, more generally, the other control variables. As in the main estimations, the impact of human capital remains larger than that of financial development. It is important to notice here that inflation and the crises variable become significant in most equations and have the expected signs. The other remaining variables have the expected signs but are not significant. The coefficient of determination is very low in equations (1), (2) and (7) but augments tremendously when we control for inflation and human capital. The F-test is statistically significant in all equations.

Table 2.7 presents the results of the estimations for the developing countries. As in the previous regressions, REER volatility influences negatively total factor productivity growth. But conversely to the previous results, the effect of REER volatility is very high. Referring to regression (1), an increase in REER volatility by 100% reduces total factor productivity growth by an amount equivalent to 2.41 percentage points. This is approximately 7 times the effect of REER volatility we calculated for the overall sample. This suggests that REER volatility is more harmful to developing countries than to developed countries. Just as in the developed countries, the coefficient of REER volatility is stable and its standard error is small. Openness continues to influence positively TFPG. The F-test is statistically significant but the coefficient of determination is very low.

In Table 2.8, we present the estimation results using the second measurement of REER volatility. We see that REER volatility continues to affects negatively TFPG. As in the main results, the effect of REER volatility is not very high. The standard error of the coefficient of REER volatility is also very low, suggesting a high degree of precision in the estimation of this coefficient. Contrarily to the main estimations, the coefficient of REER volatility remains stable when we introduce financial development and human capital, signifying that the effect of REER volatility on total factor productivity growth may not pass through these variables when we use this second measurement of REER volatility. Like in the main regressions, the impact of human capital and openness are greater than that of financial development. The other control variables have the expected signs but are not significant. The F-test is significant in all equations. The R-squared is very low but increases hugely when we introduce human capital.

### 2.5.2 Threshold effect estimation results

Table 2.9 gives the results of the regressions using the threshold effect estimation method *(Hansen (1999))*. Before examining the results, it is important to note that the *Hansen (1999)* method is designed for balanced panel data. Hence, we had to eliminate the missing values from our sample of study. Consequently, we had only 54 countries with a total of 270 observations left out of 74 countries and from sub-periods 1980-1984 to 2000-2004. This drastically reduces the number of observations, but we have a sufficient number of observations on which we can conduct statistical inference. Also for these estimations we use the second measurement of REER volatility. The upper part of Table 2.9 provides the test for the existence of threshold effects in the estimated equations while the lower part gives the coefficient estimates. The results illustrate that there does not exist a first or a second threshold but there is a third threshold in all equations. This, because the bootstrapped p-values show that the triple threshold is statistically significant at 10% level. Moreover referring to regression 4 in Table 2.9, Figure 2.6 depicts that the $LR_3(\gamma)$ curve touches the x-axis between (-1.5) and (-1.0). Hence there exists a triple threshold value $\hat{\gamma}$ between these two values. The estimate of this threshold is very precise since the confidence interval for this parameter is very narrow. Recall that the confidence interval for the threshold parameter corresponds to the values of $LR_3(\gamma)$ that are below the dashed horizontal line. The coefficient of REER volatility below the second threshold is highly statistically significant but since the corresponding threshold is not significant, we conclude that REER volatility has no impact on total factor productivity growth at this threshold level. Thus for very low levels of financial development, REER volatility has no effect on total factor productivity growth. On the other hand, the coefficient of REER volatility below the third threshold is negative, highly significant and its corresponding threshold is also statistically significant. Consequently, for moderately financially developed countries, REER volatility reacts negatively on productivity. Although this negative effect is not economically very high, it remains robust to the introduction of control variables. It is also very precise since its standard errors are very small. The coefficient of REER volatility above the third threshold is positive but is not statistically significant. Hence for highly financially developed countries, REER volatility has no impact on productivity. Referring to equation (4), we see that the estimated triple threshold is equal to (-1.216962) and keeps the same value across all equations. The corresponding level of financial development is 0.2961. This value is slightly below the median of financial development. This illustrates that there are a lot of countries above this threshold level and that it is not out of sample. As in the main estimations in Table 2.5, openness has a larger effect than financial development. But contrarily to the main results, government consumption and inflation are significant and have the expected signs.

In short, the intuition behind the conditioning on the level of financial development is that countries that are less financially developed do not have the substructure (large investment, good capital stock, high financial interlinks) to make them defenseless against REER volatility. They have to become a little big for REER volatility to play. In contrast in countries that are moderately financially developed, the financial interconnections are fairly large and many firms are linked financially. Hence any REER volatility can damage the system. Finally countries that are highly financially developed have many insurance and protection mechanisms that protect them against the damaging effects of REER volatility.

## 2.6 Conclusion

For a long time, economists were not interested in the relation between business cycle and economic growth but since *Ramey and Ramey (1995)*, the number of works studying this link has exploded. In line with these studies, the connection between real exchange rate volatility and productivity growth has also recently been examined. The theory suggests that real exchange rate volatility acts on productivity according to some threshold variable: financial development or liability dollarization. We studied the effects of REER volatility on total factor productivity growth using a panel data of 74 countries from 1975 to 2004. Using panel data instrumental variables and threshold effects estimation methods, we first found that REER volatility affects negativity total factor productivity growth and second, we discovered that this impact of REER volatility depends on the level of financial development of the countries.

Although the results were lighting, some warnings deserve to be underlined. Firstly, we did not include liability dollarization or an equivalent measurement beside financial development as a threshold variable. Secondly, although the threshold effect estimation method takes into account the unobservable heterogeneity of the countries, it does not control for the endogeneity of REER volatility[23]. Thirdly, we did not isolate, empirically, the precise channels through which REER volatility affects total factor productivity growth nor have we studied the impact of REER volatility on the components of productivity growth.

From policy perspectives, the results found in this chapter indicate that the negative effects of REER volatility in the long term are not negligible. Hence efforts made in reducing REER volatility will be translated, in the long-run, by huge productivity gains.

[23] There does not exist, to this date, a method of estimation of threshold effects with instrumental variables on panel data.

In the first chapter, we provided some theoretical arguments on the channels through which the REER or its associated measurements can affect productivity. Two of the identified channels are through investment and exports. In the two remaining chapters we test the assumptions that the effects of REER or its associated measurements on productivity may pass through investment and exports. This is why the next chapter studies the relationship between REER volatility and investment.

# Appendices of Chapter 2

## Table 2.1: Definitions and methods of calculation of the control variables

| Variables | Definitions | Expected Sign | Sources of data |
|---|---|---|---|
| Financial development | log of domestic credit to private sector over GDP | Positive | World Development Indicators, 2006 |
| Openness | log of exports + imports to GDP | Positive | |
| Human capital | log of the average number of years of studies in the secondary. The initial value of this variable was taken for each period. | Positive | Barro and Lee (2010) |
| Government consumption | log of government consumption over GDP | Negative | World Development Indicators, 2006 |
| Inflation | log of one plus inflation rate | Negative | World Development Indicators, 2006, and International Financial Statistics (IFS), April 2006 |
| Tendency of terms of trade | growth rate of terms of trade | Positive | World Development Indicators, 2006 |
| Crises | = 1 if banking or financial crises<br>= 0 otherwise | Negative | Caprio and Klingebiel (2003), and Kaminski and Reinhart (1999) |

Note: For the definitions and source of the total factor productivity growth and the real effective exchange rate volatility variables, see the text.

## **Table 2.2:** Summary statistics for all the variables

| Variables | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Total Factor Productivity Growth | 362 | 0.0276 | 0.0414 | -0.1017 | 0.1883 |
| REER volatility 1+ | 386 | 1.5074 | 2.6431 | -12.1301 | 8.0975 |
| REER volatility 2+ | 389 | 0.3282 | 2.7418 | -8.0648 | 8.7680 |
| Financial development+ | 437 | -1.0920 | 0.8415 | -3.9535 | 3.4597 |
| Openness+ | 438 | -0.5024 | 0.5765 | -2.1324 | 1.1490 |
| Human capital+ | 426 | 0.3724 | 0.8158 | -2.8189 | 1.7444 |
| Government consumption+ | 443 | -1.9603 | 0.4028 | -3.2156 | -0.6093 |
| Inflation+ | 444 | 0.1623 | 0.3944 | -0.0231 | 3.5432 |
| Tendency of terms of trade | 438 | 0.0028 | 0.0431 | -0.1376 | 0.2620 |
| Crises | 360 | 0.2118 | 0.3195 | 0 | 1 |

Note: +These variables are measured in logarithms

## Table 2.3: List of the 74 countries in the studied sample

| Developed countries | | | Developing Countries | | | | | |
|---|---|---|---|---|---|---|---|---|
| No. | World Bank Code | Countries | No. | World Bank Code | Countries | No. | World Bank Code | Countries |
| 1 | AUS | Australia | 1 | ARG | Argentina | 25 | HND | Honduras |
| 2 | AUT | Austria | 2 | BDI | Burundi | 26 | HTI | Haiti |
| 3 | BEL | Belgium | 3 | BEN | Benin | 27 | HUN | Hungary |
| 4 | CAN | Canada | 4 | BFA | Burkina Faso | 28 | IDN | Indonesia |
| 5 | CHE | Switzerland | 5 | BGD | Bangladesh | 29 | IND | India |
| 6 | DEU | Germany | 6 | BOL | Bolivia | 30 | IRN | Iran, Islamic Rep. |
| 7 | DNK | Denmark | 7 | BRA | Brazil | 31 | JOR | Jordan |
| 8 | ESP | Spain | 8 | BWA | Botswana | 32 | KEN | Kenya |
| 9 | FIN | Finland | 9 | CHL | Chile | 33 | LKA | Sri Lanka |
| 10 | GBR | United Kingdom | 10 | CHN | China | 34 | LSO | Lesotho |
| 11 | GRC | Greece | 11 | CIV | Cote d'Ivoire | 35 | MAR | Morocco |
| 12 | HKG | Hong Kong, China | 12 | CMR | Cameroon | 36 | MEX | Mexico |
| 13 | IRL | Ireland | 13 | COG | Congo, Rep. | 37 | MLI | Mali |
| 14 | ISL | Iceland | 14 | COL | Colombia | 38 | MRT | Mauritania |
| 15 | ITA | Italy | 15 | CRI | Costa Rica | 39 | MWI | Malawi |
| 16 | JPN | Japan | 16 | DOM | Dominican Republic | 40 | MYS | Malaysia |
| 17 | KOR | Korea, Rep. | 17 | DZA | Algeria | 41 | NIC | Nicaragua |
| 18 | LUX | Luxembourg | 18 | ECU | Ecuador | 42 | PAK | Pakistan |
| 19 | NLD | Netherlands | 19 | GAB | Gabon | 43 | PER | Peru |
| 20 | NOR | Norway | 20 | GHA | Ghana | 44 | PHL | Philippines |
| 21 | NZL | New Zealand | 21 | GMB | Gambia, The | 45 | PRY | Paraguay |
| 22 | PRT | Portugal | 22 | GNB | Guinea-Bissau | 46 | SEN | Senegal |
| 23 | SGP | Singapore | 23 | GTM | Guatemala | 47 | SLV | El Salvador |
| 24 | SWE | Sweden | 24 | GUY | Guyana | 48 | SWZ | Swaziland |
| | | | | | | 49 | TGO | Togo |
| | | | | | | 50 | THA | Thailand |

## **Table 2.4:** Estimation of the translog stochastic production function

| Dependent variable: ln $y$ | | |
|---|---|---|
| Regressors | Coefficients | Std. Err. |
| $t$ | -0.0121 | 0.0723 |
| $(1/2)t^2$ | 0.0069* | 0.0041 |
| $\ln K$ | 0.2323 | 0.1754 |
| $\ln L$ | -0.7615*** | 0.2695 |
| $(1/2)(\ln K)^2$ | 0.0327*** | 0.0098 |
| $(1/2)(\ln L)^2$ | 0.1240*** | 0.0255 |
| $\ln K \ln L$ | -0.0304* | 0.0160 |
| $t \ln K$ | 0.0102*** | 0.0028 |
| $t \ln L$ | -0.0173*** | 0.0046 |
| Constant | 17.5921*** | 2.9582 |
| $\mu$ | 0.0682 | 0.2992 |
| $\eta$ | 0.0852*** | 0.0097 |
| $\ln \sigma_S^2$ | -1.4390*** | 0.5071 |
| Inverse logit of $\gamma$ | 3.0663*** | 0.5359 |
| $\sigma_S^2$ | 0.2372 | 0.1203 |
| $\gamma$ | 0.9555 | 0.0228 |
| $\sigma_u^2$ | 0.2266 | 0.1203 |
| $\sigma_v^2$ | 0.0106 | 0.0008 |

Note: *** p<0.01, ** p<0.05, * p<0.1

**Table 2.5: Panel data instrumental variable estimation results for all countries with the variable real effective exchange rate volatility 1**

| Dependent Variable: Total factor productivity growth | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regressors | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| REER volatility 1+ | -0.0143*** | -0.00407** | -0.00413** | -0.0141** | -0.00343** | -0.00412** | -0.00362* | -0.00339* |
| | (0.00550) | (0.00205) | (0.00202) | (0.00545) | (0.00172) | (0.00202) | (0.00187) | (0.00172) |
| Openness+ | 0.0166* | | | 0.0169* | | | | |
| | (0.00869) | | | (0.00867) | | | | |
| Human capital+ | | 0.0399*** | 0.0387*** | | 0.0382*** | 0.0386*** | 0.0377*** | 0.0381*** |
| | | (0.00299) | (0.00296) | | (0.00310) | (0.00298) | (0.00318) | (0.00310) |
| Financial development+ | | | 0.00511*** | | 0.00522*** | 0.00522*** | 0.00518*** | 0.00535*** |
| | | | (0.00174) | | (0.00171) | (0.00177) | (0.00175) | (0.00174) |
| Inflation+ | | | | -0.000573 | | | | |
| | | | | (0.00597) | | | | |
| Government consumption+ | | | | -0.00726 | | -0.00148 | | -0.00181 |
| | | | | (0.0101) | | (0.00469) | | (0.00474) |
| Crises | | | | | -0.000423 | | -0.000166 | -0.000476 |
| | | | | | (0.00286) | | (0.00295) | (0.00286) |
| Tendency of terms of trade | | | | | | | 4.51e-05 | |
| | | | | | | | (0.0220) | |
| Constant | 0.0584*** | 0.0147*** | 0.0210*** | 0.0441** | 0.0202*** | 0.0183* | 0.0209*** | 0.0167 |
| | (0.00975) | (0.00429) | (0.00448) | (0.0213) | (0.00437) | (0.00953) | (0.00452) | (0.0102) |
| Observations | 306 | 296 | 294 | 306 | 234 | 294 | 229 | 234 |
| Number of countries | 69 | 67 | 67 | 69 | 54 | 67 | 53 | 54 |
| F test | 6.9760 | 95.16 | 67.50 | 3.754 | 49.29 | 50.46 | 36.55 | 39.49 |
| P-value F | 0.00114 | 0 | 0 | 0.00557 | 0 | 0 | 0 | 0 |
| R-squared overall | 0.00114 | 0.142 | 0.150 | 0.00239 | 0.234 | 0.149 | 0.232 | 0.235 |

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
+ These variables are measured in logarithms

**Table 2.6: Panel data instrumental variable estimation results for developed countries with the variable real effective exchange rate volatility 1**

| Dependent Variable: Total factor productivity growth | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regressors | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| REER volatility 1+ | -0.00688** | -0.00630** | -0.00475** | -0.00311* | -0.00327* | -0.00313* | -0.00758** | -0.00332* |
| | (0.00293) | (0.00283) | (0.00199) | (0.00184) | (0.00176) | (0.00185) | (0.00362) | (0.00179) |
| Financial development+ | 0.00828** | 0.00669* | | | | | 0.00803** | |
| | (0.00351) | (0.00348) | | | | | (0.00368) | |
| Crises | | -0.0120* | -0.00863* | | -0.00601 | | | -0.00593 |
| | | (0.00709) | (0.00497) | | (0.00406) | | | (0.00413) |
| Inflation+ | | | -0.173*** | -0.131*** | -0.121*** | -0.132*** | | -0.125*** |
| | | | (0.0271) | (0.0288) | (0.0271) | (0.0310) | | (0.0291) |
| Human capital+ | | | | 0.0305*** | 0.0324*** | 0.0306*** | | 0.0328*** |
| | | | | (0.0101) | (0.0105) | (0.0102) | | (0.0107) |
| Government consumption+ | | | | | | -0.00148 | | -0.00640 |
| | | | | | | (0.0156) | | (0.0166) |
| Tendency of terms of trade | | | | | | | 0.0377 | |
| | | | | | | | (0.0960) | |
| Constant | 0.0566*** | 0.0642*** | 0.0661*** | 0.0170 | 0.0218 | 0.0144 | 0.0584*** | 0.0103 |
| | (0.00688) | (0.00794) | (0.00563) | (0.0150) | (0.0160) | (0.0320) | (0.00819) | (0.0341) |
| Observations | 102 | 72 | 74 | 104 | 74 | 104 | 97 | 74 |
| Number of countries | 24 | 17 | 17 | 24 | 17 | 24 | 23 | 17 |
| F test | 5.8210 | 3.681 | 18.07 | 31.42 | 25.29 | 23.20 | 3.233 | 19.69 |
| P-value F | 0.00445 | 0.0177 | 3.03e-08 | 0 | 0 | 0 | 0.0273 | 5.89e-11 |
| R-squared overall | 0.000941 | 0.00734 | 0.137 | 0.174 | 0.203 | 0.173 | 0.00563 | 0.188 |

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
+ These variables are measured in logarithms

**Table 2.7: Panel data instrumental variable estimation results for developing countries with the variable real effective exchange rate volatility 1**

| Dependent Variable: Total factor productivity growth | | |
|---|---|---|
| Regressors | (1) | (2) |
| REER volatility 1+ | -0.0241* | -0.0158** |
| | (0.0145) | (0.00699) |
| Openness+ | 0.0243* | 0.0214** |
| | (0.0134) | (0.0106) |
| Government consumption+ | | -0.0048 |
| | | (0.0112) |
| Crises | | 0.0139 |
| | | (0.0105) |
| Constant | 0.0690*** | 0.0415 |
| | (0.0256) | (0.0267) |
| | | |
| Observations | 207 | 172 |
| Number of countries | 46 | 39 |
| F test | 2.483 | 2.329 |
| P-value F | 0.0867 | 0.0595 |
| R-squared overall | 0.0043 | 0.0152 |

Note: Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
+ These variables are measured in logarithms

**Table 2.8: Panel data instrumental variable estimation results for all countries with the variable real effective exchange rate volatility 2**

| Dependent Variable: Total factor productivity growth | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regressors | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| REER volatility 2+ | -0.00355* | -0.00857** | -0.00627** | -0.00768** | -0.00744** | -0.00299* | -0.00355* | -0.00626** |
| | (0.00195) | (0.00345) | (0.00300) | (0.00381) | (0.00369) | (0.00170) | (0.00191) | (0.00308) |
| Inflation+ | | -0.00252 | | | -0.000487 | | | |
| | | (0.00533) | | | (0.00478) | | | |
| Government consumption+ | | -0.00549 | | -0.00472 | | | -7.67e-05 | |
| | | (0.00950) | | (0.00845) | | | (0.00505) | |
| Financial development+ | 0.00609*** | 0.00748** | 0.00522* | 0.00589* | 0.00550* | 0.00599*** | 0.00608*** | 0.00523* |
| | (0.00189) | (0.00359) | (0.00302) | (0.00335) | (0.00326) | (0.00183) | (0.00193) | (0.00302) |
| Human capital+ | 0.0372*** | | | | | 0.0366*** | 0.0372*** | |
| | (0.00335) | | | | | (0.00357) | (0.00337) | |
| Openness+ | | | 0.0137* | 0.0169** | 0.0167** | | | 0.0136* |
| | | | (0.00738) | (0.00709) | (0.00691) | | | (0.00737) |
| Crises | | | -0.000302 | | | -0.000748 | | -0.000304 |
| | | | (0.00483) | | | (0.00297) | | (0.00484) |
| Tendency of terms of trade | | | | | | | | 0.00181 |
| | | | | | | | | (0.0378) |
| Constant | 0.0165*** | 0.0258 | 0.0410*** | 0.0329** | 0.0417*** | 0.0168*** | 0.0164 | 0.0410*** |
| | (0.00312) | (0.0185) | (0.00474) | (0.0165) | (0.00459) | (0.00335) | (0.00994) | (0.00474) |
| Observations | 296 | 309 | 240 | 304 | 305 | 236 | 295 | 240 |
| Number of countries | 67 | 70 | 55 | 69 | 69 | 54 | 67 | 55 |
| F test | 58.82 | 2.900 | 4.160 | 4.007 | 4.342 | 44.39 | 43.57 | 3.422 |
| P-value F | 0 | 0.0227 | 0.00301 | 0.00367 | 0.00210 | 0 | 0 | 0.00560 |
| R-squared overall | 0.149 | 0.00441 | 0.00848 | 0.00460 | 0.00636 | 0.224 | 0.149 | 0.00863 |

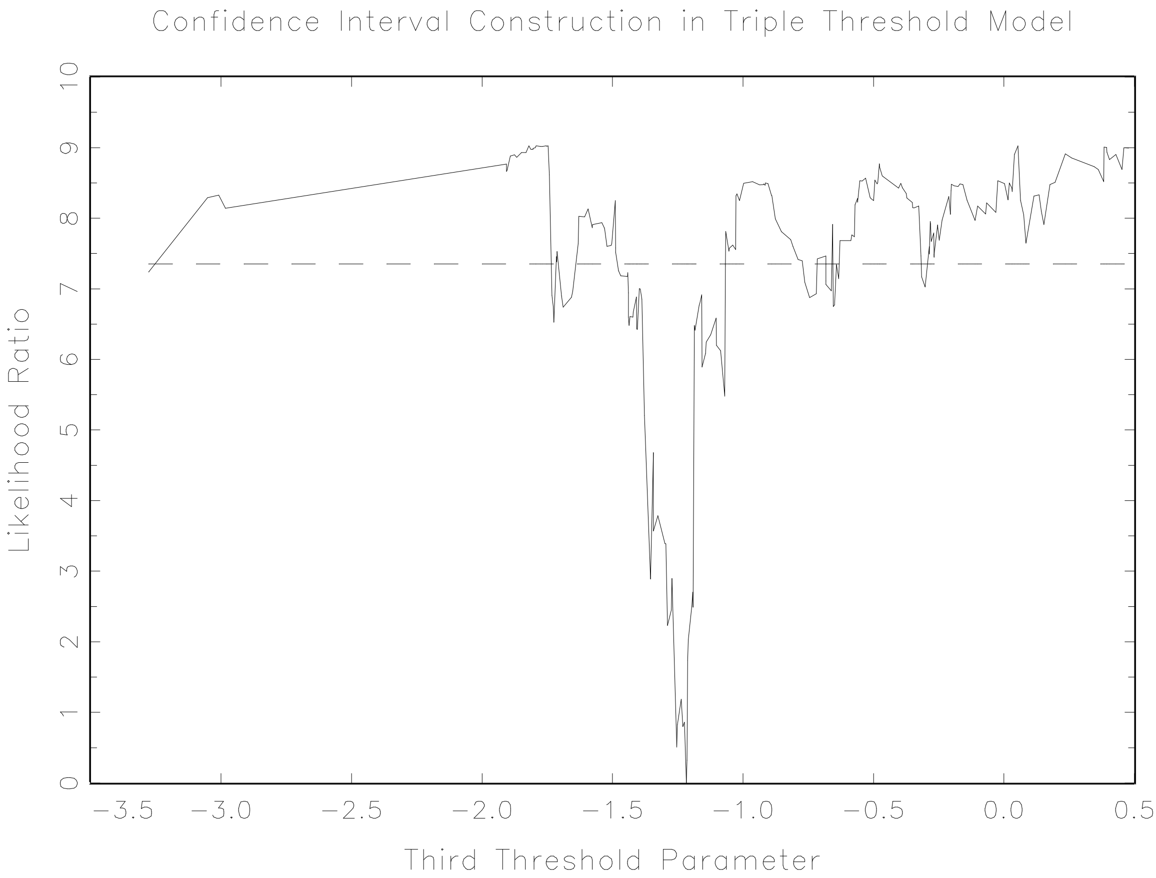
Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
+ These variables are measured in logarithms

**Table 2.9: Threshold effect estimation method for all countries with the variable real effective exchange rate volatility 2**

| Dependent Variable: Total factor productivity growth | | | | |
|---|---|---|---|---|
| Regressors | (1) | (2) | (3) | (4) |
| Estimated single threshold | -2.180058 | -2.180058 | -2.180058 | -2.180058 |
| F1 single threshold | 9.384393 | 9.278434 | 9.015172 | 8.793222 |
| Bootstrap p-value single threshold | [0.216667] | [0.290000] | [0.246667] | [0.303333] |
| Estimated double threshold | -2.110279 | -2.110279 | -2.110279 | -2.110279 |
| F1 double threshold | 9.698860 | 10.228568 | 9.388542 | 9.877381 |
| Bootstrap p-value double threshold | [0.163333] | [0.166667] | [0.236667] | [0.196667] |
| Estimated triple threshold | -1.216962 | -1.216962 | -1.216962 | -1.216962 |
| F1 triple threshold | 9.543235* | 9.435386* | 9.243788* | 9.025115* |
| Bootstrap p-value triple threshold | [0.060000] | [0.090000] | [0.086667] | [0.086667] |
| REER volatility 2 threshold 1+ | 0.000244 | 0.000369 | 0.000285 | 0.000434 |
| | (0.001406) | (0.001358) | (0.001399) | (0.001345) |
| REER volatility 2 threshold 2+ | 0.008188*** | 0.008205*** | 0.008103*** | 0.008089*** |
| | (0.001729) | (0.001699) | (0.001766) | (0.001747) |
| REER volatility 2 threshold 3+ | -0.002226*** | -0.002194*** | -0.002164*** | -0.002106*** |
| | (0.000725) | (0.000728) | (0.000733) | (0.000739) |
| REER volatility 2 threshold 4+ | 0.000174 | 0.000173 | 0.000200 | 0.000208 |
| | (0.000364) | (0.000367) | (0.000366) | (0.000366) |
| Openness+ | 0.013826*** | 0.013617*** | 0.013489*** | 0.013137*** |
| | (0.004273) | (0.004217) | (0.004290) | (0.004221) |
| Financial development+ | 0.006615*** | 0.007448*** | 0.006409*** | 0.007220*** |
| | (0.001915) | (0.002179) | (0.001902) | (0.002154) |
| Government consumption+ | | -0.010631** | | -0.011353** |
| | | (0.005249) | | (0.005263) |
| Inflation | | | -0.002083 | -0.002871* |
| | | | (0.001572) | (0.001711) |
| Observations | 270 | 270 | 270 | 270 |
| Number of countries | 54 | 54 | 54 | 54 |

Note: P-values in square brackets; robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Number of Bootstrap replications 300
+ These variables are measured in logarithms

**Figure 2.6: Confidence interval for the triple threshold effect (regression 4 in Table 1.9)**



## Table 2.10: Correlations between all the variables

| | TFPG | REER volatility 1 | REER volatility 2 | Financial development | Openness | Human capital | Gov. consumption | Inflation | Tend. of terms of trade | Crises |
|---|---|---|---|---|---|---|---|---|---|---|
| TFPG | 1.0000 | | | | | | | | | |
| | 362 | | | | | | | | | |
| REER volatility 1 | 0.0584 | 1.0000 | | | | | | | | |
| | 0.2917 | | | | | | | | | |
| | 328 | 386 | | | | | | | | |
| REER volatility 2 | 0.0057 | 0.6385* | 1.0000 | | | | | | | |
| | 0.9183 | 0.0000 | | | | | | | | |
| | 329 | 386 | 389 | | | | | | | |
| Financial development | 0.2590* | 0.1190* | 0.1637* | 1.0000 | | | | | | |
| | 0.0000 | 0.0203 | 0.0013 | | | | | | | |
| | 359 | 380 | 383 | 437 | | | | | | |
| Openness | -0.0377 | -0.1252* | -0.0561 | 0.1609* | 1.0000 | | | | | |
| | 0.4778 | 0.0146 | 0.2731 | 0.0008 | | | | | | |
| | 357 | 380 | 383 | 431 | 438 | | | | | |
| Human capital | 0.3456* | 0.1263* | 0.1088* | 0.5278* | 0.1589* | 1.0000 | | | | |
| | 0.0000 | 0.0154 | 0.0362 | 0.0000 | 0.0011 | | | | | |
| | 347 | 368 | 371 | 421 | 420 | 426 | | | | |
| Gov. consumption | 0.0981* | -0.0449 | 0.0278 | 0.2938* | 0.3403* | 0.2011* | 1.0000 | | | |
| | 0.0625 | 0.3800 | 0.5852 | 0.0000 | 0.0000 | 0.0000 | | | | |
| | 361 | 385 | 388 | 436 | 437 | 425 | 443 | | | |
| Inflation | -0.0744 | 0.0191 | 0.0122 | -0.1560* | -0.2428* | -0.0418 | -0.0836* | 1.0000 | | |
| | 0.1577 | 0.7087 | 0.8108 | 0.0011 | 0.0000 | 0.3893 | 0.0787 | | | |
| | 362 | 386 | 389 | 437 | 438 | 426 | 443 | 444 | | |
| Tend. of terms of trade | 0.0628 | -0.0486 | -0.0167 | -0.0712 | 0.0218 | -0.0147 | -0.0203 | 0.0074 | 1.0000 | |
| | 0.2368 | 0.3445 | 0.7445 | 0.1401 | 0.6494 | 0.7645 | 0.6726 | 0.8770 | | |
| | 357 | 380 | 383 | 431 | 438 | 420 | 437 | 438 | 438 | |
| Crises | -0.0210 | 0.0758 | 0.0274 | 0.0383 | -0.1309* | 0.0475 | -0.0990* | 0.2556* | -0.0077 | 1.0000 |
| | 0.7213 | 0.1856 | 0.6312 | 0.4733 | 0.0137 | 0.3774 | 0.0609 | 0.0000 | 0.8847 | |
| | 292 | 307 | 310 | 353 | 354 | 348 | 359 | 360 | 354 | 360 |

Note: * significant at 10% level

# PART II:

# TRANSMISSION CHANNELS OF THE REAL EFFECTIVE EXCHANGE RATE AND ITS ASSOCIATED MEASUREMENTS TO PRODUCTIVITY

# Chapter 3:

# Exchange Rate Volatility and Investment: A Panel Data Cointegration Approach

# 3.1 Introduction

Multiples efforts have been deployed by governments and international organizations to maintain a stable macroeconomic environment in developing countries but, unfortunately, instability still remains one of their greatest economic problems. Figure 3.1 in the appendices of chapter 3 illustrates that instability is far higher in developing countries than in developed ones even in recent years. The case of 1984-1989 sub-period is particularly striking because instabilities (exchange rate instability, exports instability and terms of trade instability) are particularly high[24]. At the same time, Figure 3.2 in the appendices of chapter 3 shows that for the whole period 1975-2004, investment in developing countries is less important than in industrialized countries. This brings us to ask the following questions: can volatility, particularly real exchange rate volatility, lessen investment in developing countries? What are the channels through which exchange rate and exchange rate volatility affect investment? The chapter attempts to analyze these issues.

The theoretical literature on the link investment-exchange rate concentrates on the adjustment costs of investment theory which state the existence of costs attached to the acquisition of new capital. Most studies focus on internal adjustment costs. For example, costs associated with the installation of new capital and/or training of employees to the use of the new equipment. To study the link exchange rate-investment, *Campa and Goldberg (1999)*, *Nucci and Pozzolo (2001)*, *Harchaoui, Tarkhani and Yuen (2005)*, with minor differences in their formulations, employ discrete dynamic optimization problems with a standard adjustment-cost model of a firm which operates in an imperfect uncertain environment. The firm sells one part of

[24] We will employ without distinction the terms instability and volatility. Instabilities presented in Figure 3.1 are from *Guillaumont (2006)* (variable *Instability, 6 previous years ex-post, global adjustment*; see *Guillaumont (2006)* for further details). In the econometric section, we use Autoregressive Conditional Heteroskedasticity Family (ARCH-Family) methods to compute the exchange rate instability, see subsection 3.3.2. Furthermore, in Figure 3.1 we do not present other instabilities like GDP instability and inflation instability due to legibility problems.

its production in the domestic market and exports the other part abroad. In both of these markets the firm has a markup power, which means it can influence the prices. The firm also imports some part of its inputs from abroad. The common findings of these studies can be classified in three categories. First, exchange rate affects investment through domestic and export sales. When currency depreciates, domestic goods become less expensive than imported goods, resulting to an increase of demand on domestic goods. In the same way, exports increase because they are cheaper. For a given capital and labor, marginal revenue products of capital and labor increase as a result of convenient demands situations. The firm responds by increasing its investment in capital and, consequently, labor. Second, exchange rate acts on investment through the prices of imported inputs. Depreciation raises total production costs which results in lower marginal profitability. The impact of the exchange rate on the marginal profitability is proportional to the share of imported inputs into production. Third, in their results, *Harchaoui et al. (2005)* shows that exchange rate can also affect investment through the price of imported investment via adjustment-cost. Depreciation causes an increase of investment price, resulting to higher adjustment costs and lower investment. Overall, it is important to note that the global impact of exchange rate on investment is not obvious because it depends on which of these previous effects prevail and the values of elasticities of demands.

The theoretical link investment-exchange rate volatility has also been the subject of many studies. *Campa and Goldberg (1995)* apply the same formulation as above and assume that the exchange rate is log-normally distributed. The model predicts that the effects of exchange rate uncertainty on profits are ambiguous. Increases in exchange rate augment expected profit if the firm exports more than it imports and lower expected profit in the opposite case. *Goldberg (1993)*, using a duality theory, and *Darby, Hallett, Ireland and Piscitelli (1999)* an adapted model of *Dixit and Pindyck (1994)*, found the same threshold effects of exchange rate uncertainty on investment.

The empirical relation between the exchange rate, its volatility and investment has been analyzed both in developed and developing countries.

For developed countries almost all studies are in the industry-level. Various methods are used for the empirical investigation: OLS, Two-Stage Least Squares, VARS, GMM, etc. Utilizing a large sample of industries, *Goldberg (1993)* discovered that the effects of exchange rate and its volatility on investment in the United States are more visible in the 1980s than in the 1970s. In the 1980s, the dollars had significant differentiated impacts on industries. While the dollars had ambiguous effects on nonmanufacturing industries, its depreciations (appreciations) decreased (increased) investment in manufacturing nondurables sectors. After *Goldberg (1993)*, *Goldberg, Campa* and other researchers conducted numerous works to investigate the relation investment-exchange rate in industrialized countries. The main results of these studies are first, the effect of exchange rate on investment depends on industries external exposure (United States, Japan and Italy). On the one hand, industries which rely heavily on imports are more likely to record decreases in investment after exchange rate depreciation. On the other hand, industries which have large export shares tend to increase investment after exchange rate depreciation. Second, industries with lower pricing power (lower markups) are significantly influenced by appreciation and depreciation (United States, United Kingdom and Japan). Contrary, industries with higher markups tend to be insensitive to exchange rate movements (*Campa and Goldberg (1995)*, *Campa and Goldberg (1999)*, *Nucci and Pozzolo (2001)*, and *Atella, Atzeni and Belvisi (2003)*[25]). Third, persistent exchange rate volatility contributes to investment volatility in the United States, *Campa and Goldberg (1999)*. Fourth, differences in investment response across

[25] *Nucci and Pozzolo (2001)* and *Atella et al. (2003)* use firm-level panel data.

countries and industries could be partially explained by institutional factors: access to credit market, belonging to an industrial group, etc. Moreover, *Campa and Goldberg (1999)*, *Lafrance and Tessier (2001)*, and *Harchaoui et al. (2005)* have found that investment does not respond to exchange rate in Canada. But further investigations of *Harchaoui et al. (2005)* highlight the existence of nonlinear effects of exchange rate on investment. Exchange rate depreciations (appreciations) have positive (negative) effects on investment when the exchange rate volatility is low. This reveals the necessity of differentiating investment response between high and low exchange rate volatility in Canada.

Beside these studies on industries or firm levels, *Darby et al. (1999)* utilize aggregated investment data for five countries (France, Germany, Italy, the United Kingdom and the United States) and find that exchange rate volatility has a large negative effect on *investment*. Its impact is more important than that of exchange rate misalignment. Exchange rate stability would raise investment in Europe, in general, although France and Germany would benefit more, while Italy and United Kingdom would enjoy only temporarily gains.

Empirical investigations of the relation between the exchange rate, its volatility and investment in developing countries use, in general, OLS, Two-Stage Least Squares, Fixed effects, GMM and system GMM. *Oshikoya (1994)* results illustrate that exchange rate appreciation had a positive impact on private investment for four African Middle-Income countries (Cameroon, Mauritius, Morocco and Tunisia). For the effects of real effective exchange rate (REER) volatility, a significant negative impact of exchange rate volatility on investment is reported by the major part of the studies *(Serven (1998)*, *Bleaney and Greenaway (2001), and Serven (2002))*. The impact of exchange rate instability on investment is nonlinear. The effect is large when, firstly, volatility is high and secondly, when there is large trade openness combined with low financial development. Contrary, in an environment with low openness and high financial development, exchange rate volatility tends to act positively on investment, *Serven (2002)*. Furthermore, *Guillaumont, Guillaumont Jeanneney and Brun (1999)* find that "primary" instabilities (climatic, terms of trade and political instabilities) act on Africa growth through the negative effect that "intermediate" instabilities (instability of real exchange rate and instability of the rate of investment) exert on growth.

This chapter fits in these researches of the links between the investment and the exchange rate. But it distinguishes itself by several ways. Initially, in the theoretical part we introduce a model of a small open economy. In line with previous works, we assume the presence of internal adjustment costs of investment but we consider first, that prices and interest rates are given and second, that the firm imports capital goods rather than intermediate goods. We believe that these assumptions are more in line with the realities of developing countries than assuming the existence of pricing power for their firms. Less importantly, the model is formulated in continuous time, contrary to the discrete time specification of previous studies. The model illustrates that the impacts of exchange rate and exchange rate volatility on investment are nonlinear depending on which of between the revenue and cost channel prevail and the values of elasticities of imports and exports. In the second place, we apply panel data cointegration techniques to study the empirical relation between investment and exchange rate volatility for 51 developing countries (23 low-income and 28 middle-income countries) from1975 to 2004[26]. There are some previous studies which employ microeconomic panel data methods (Fixed Effects, GMM, etc.) on annual data with a relatively long period. But given the existence of potential unit roots in variables, these estimations could be seriously affected by spurious

[26] Countries and time period selection depend on the availability of data. See Table 3.7 for a list of countries.

regressions effects[27]. This is why we think using panel data cointegration methods is more appropriate[28]. The application of panel data cointegration techniques has several advantages. Initially, annual data enable us not to lose information contrary to the method of averages over sub-periods. Then, the addition of the cross sectional dimension makes that statistical tests are normally distributed, more powerful and do not depend on the number of regressors in the estimation as in individual time series. Among the panel data cointegration techniques, we utilize *Pedroni (1999) Fully Modified Ordinary Least Squares* (FMOLS) estimator which deals with possible autocorrelation and heteroskedasticity of the residuals, takes into account the presence of nuisance parameters, is asymptotically unbiased and, more importantly, deals with potential endogeneity of regressors. The results demonstrates firstly, that exchange rate volatility has a strong negative impact on investment, secondly, the effect of REER volatility is higher in countries which rely heavily on imports. Furthermore, robustness checks shows that this negative impact of REER volatility on investment is stable to the use of an alternative measurement of REER volatility and on subsamples of countries (low-income and middle-income developing countries).

The remaining of the chapter is organized as follow: section 3.2 presents more stylized facts on REER volatility and productivity, section 3.3 gives the theoretical models on the link between the REER or its associated measurements and investment, section 3.4 deals with the empirical investigation and the last section concludes.

[27] See *Kao (1999)* for further details on spurious regressions in panel data

[28] Colophon: For this study we use the original Program of *Pedroni (1999)* converted in RATS Procedure by Estima Corporation. *Kao and Chiang (2000)* have put together a set of GAUSS subroutines called NPT, for studying nonstationary panel data (*http://www.maxwell.syr.edu/maxpages/faculty/cdkao/working/npt.html*). The latest version of Eviews (Eviews 7) also provides many tests on panel data cointegration. I have also introduced a new User-Written Stata command named **"xtdolshm"** which performs Dynamic Ordinary Least Squares for Cointegrated Panel Data with homogeneous covariance structure *(Kao and Chiang (2000))*. This command is downloadable at :
**http://ideas.repec.org/c/boc/bocode/s457173.html**

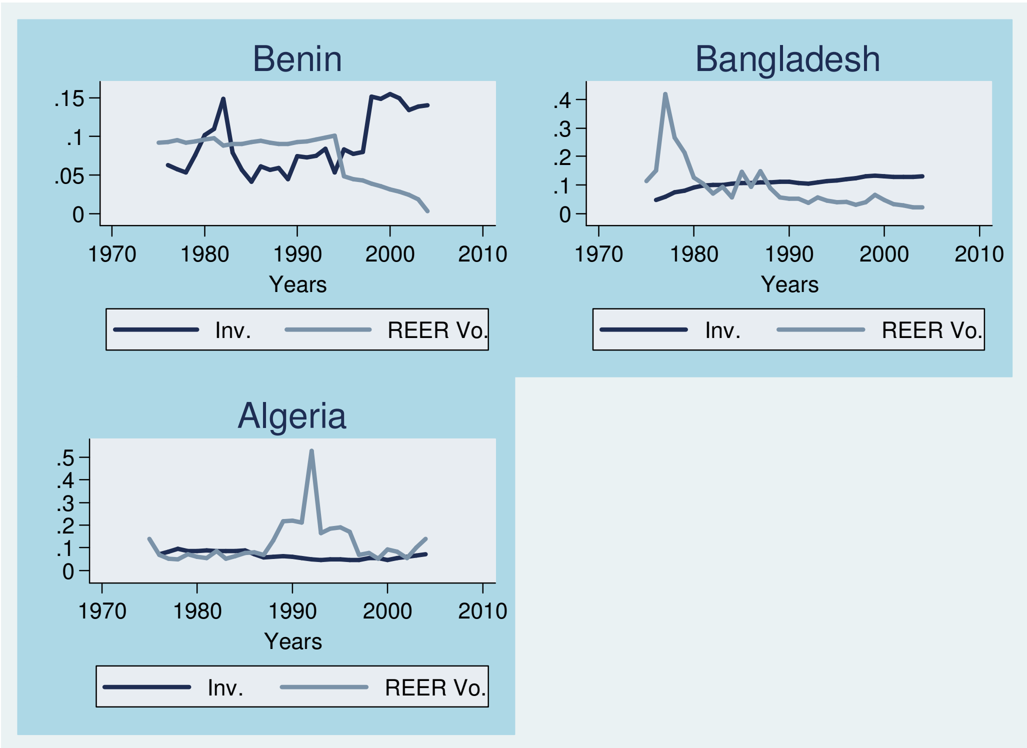
## 3.2 More Stylized Facts

In this section we expose more stylized facts related to this chapter.

- ***Evolution of Real Effective Exchange Rate Volatility and Investment by Country:***

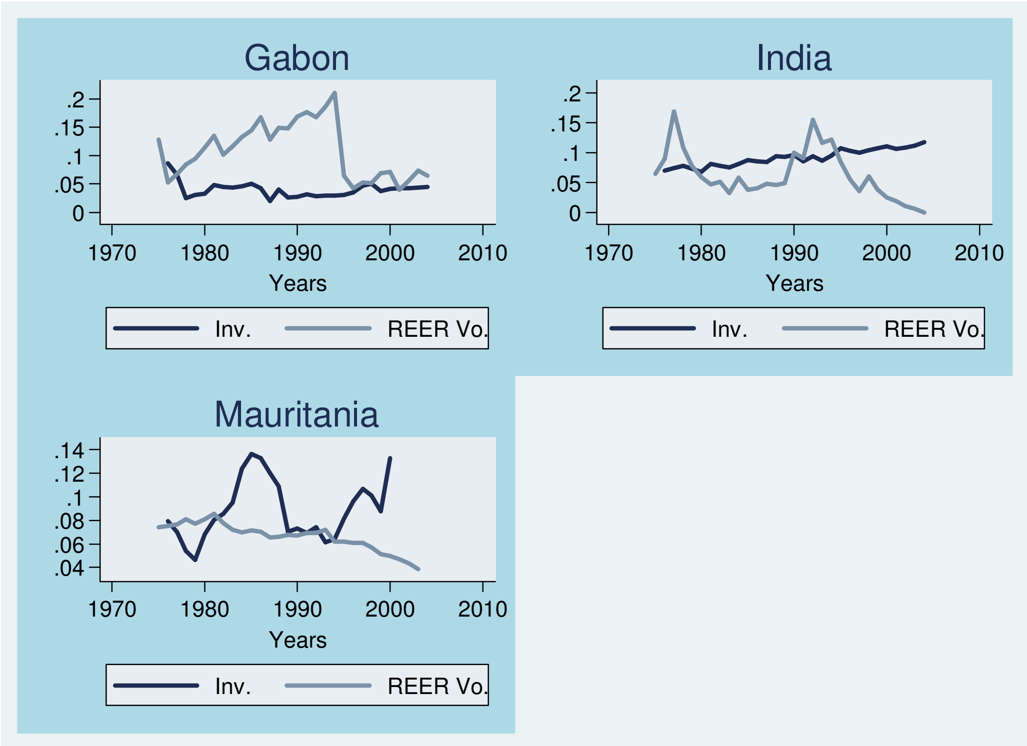
Figures 3.3 and 3.4 give the evolution of REER volatility and investment for a number of countries from 1975 to 2004. These figures demonstrate that REER volatility and investment, generally, move in opposite directions. Investment is high when REER volatility is low and vice versa. For example, in Benin, which is a member of the CFA Monetary Zone, investment increased sharply, when REER volatility started declining after the devaluation of the CFA Franc in the mid-1990s. The same thing occurred in Bangladesh at the beginning of 1980s, and in India and in Mauritania at the start of the 1990s. In Algeria, investment was very low in the 1990s since REER volatility was excessively high. Similarly, in Gabon, another member of the CFA Zone, investment was relatively low between 1980 and 2000 due to large REER volatility. But investment started to rise when REER volatility dropped drastically at the beginning of the 2000s. These two figures seem to demonstrate that investment and REER volatility are negatively correlated.

**<u>Figure 3.3:</u> Evolution of Real Effective Exchange Rate Volatility and Investment by Country (Part 1)**




Note: Investment is Investment over Lagged Capital Stock. The period of study is 1975-2004. Source: Author's calculations.

**<u>Figure 3.4:</u> Evolution of Real Effective Exchange Rate Volatility and Investment by Country (Part 2)**

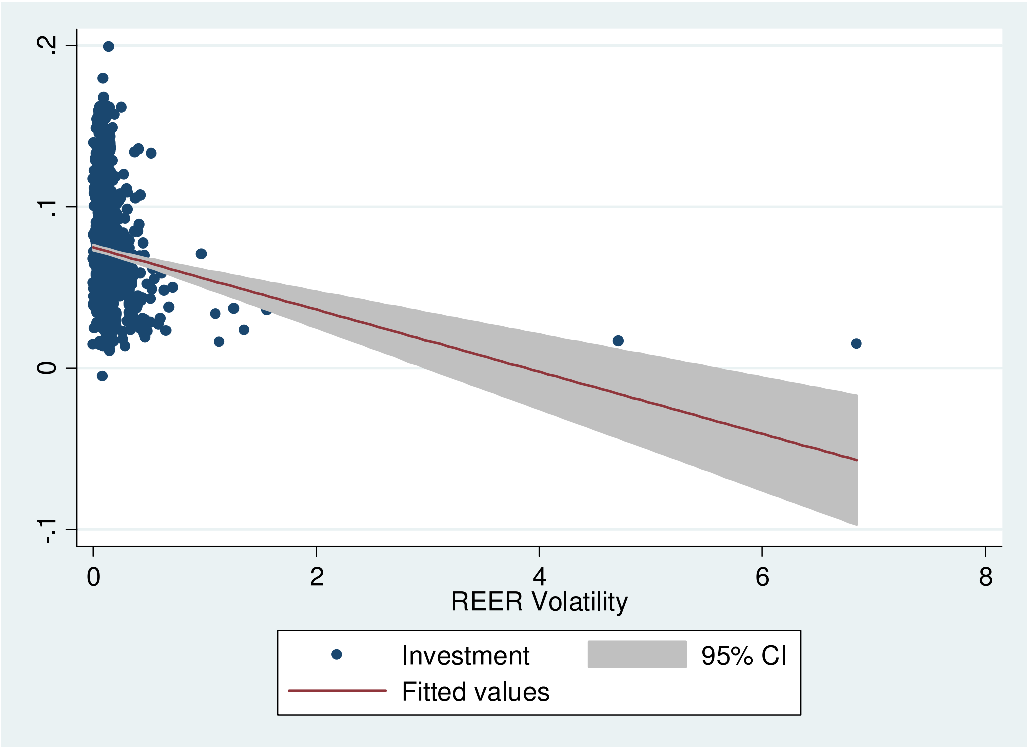



Note: Investment is Investment over Lagged Capital Stock. The period of study is 1975-2004. Source: Author's calculations.

- ***Investment in Function of the Real Effective Exchange Rate Volatility:***

Figure 3.5 demonstrates that the REER volatility may have a strong negative effect on investment. The gray area constitutes the 95% confidence interval (CI). This CI is fairly narrow for most countries. This indicates that the fitting is done with a relatively good precision for most economies. Countries with high levels of REER volatility tend to have lower values of investment. This outcome illustrates that REER volatility could, potentially, seriously harms investment.

**<u>Figure 3.5:</u> Investment in Function of the Real Effective Exchange Rate Volatility**

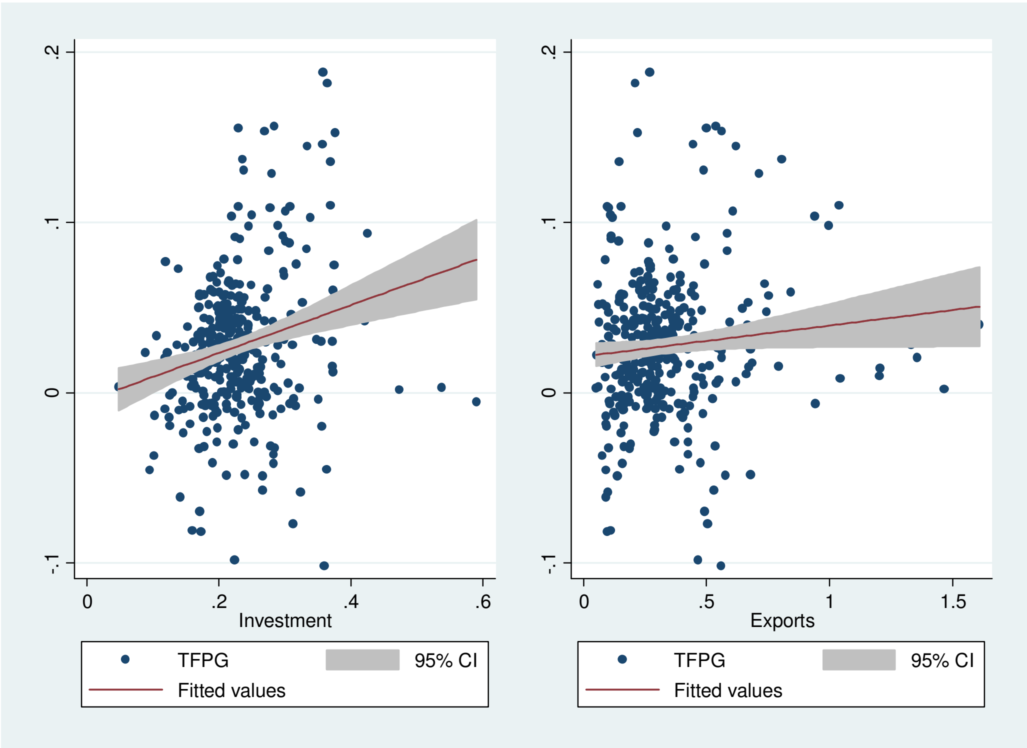



Note: Investment is Investment over Lagged Capital Stock. The period of study is 1975-2004. Source: Author's calculations.

- ***TFPG in Function of Investment and Exports***

Figure 3.6 demonstrates that TFPG is positively influenced by both investment and exports. The gray areas represent the 95% confidence intervals (CIs). The CIs are very small for most countries, indicating the precision of the fitting. An increase in investment or exports seems to raise productivity. The graph also illustrates that the potential effect of investment on productivity is more pronounced than that of exports. This figure appears to exhibit our assumptions that the impact of REER or its associated measurements on productivity may pass through investment or exports. The relationship between the associated measurements of REER and exports is studied in the next chapter. The connection between productivity and REER or its associated measurement was the subject of the two previous chapters.

**Figure 3.6: TFPG in Function of Investment and Exports**




Note: Investment is investment over GDP. Exports are the ratio of exports to GDP. The period of study is 1975-2004. Source: Author's calculations.

The graphs presented in this section show that REER volatility affects investment negatively. We also see that both investment and exports act positively on productivity. This confirms our assumptions that the impact of REER or its associated measurements on productivity may pass through investment or exports. In the following sections we investigate the negative effect of REER volatility on investment found in these stylized facts more rigorously.

# 3.3 Theoretical Framework

In this section, we present successively the model, exchange rate pass-through and the role of volatility.

## 3.3.1 The Model

In this section, we develop a model of a small open economy in which investment is subject to adjustment costs. We consider a firm which chooses its investment, $I$ [29], to maximize the present value, $V(0)$, of future profits. The production technology is neoclassical[30] and is a function of capital goods, $K$ [31].

$$Y = F(K) \tag{3.1}$$

Capital goods are homogenous but can be produced domestically or imported from abroad. The change in the firm's capital stock is given by

$$\dot{K} = I - \delta K \tag{3.2}$$

Where $\delta$ is the rate of depreciation of capital goods. The cost of each unit of investment is 1 plus an adjustment cost[32].

$$C(I) = I\left(1 + \phi\left(\frac{I}{K}\right)\right) \tag{3.3}$$

[29] We ignore time subscripts to simplify the notation. To certain extents, the model presented here could be viewed as an extended version of *Eisner and Strotz (1963)* model. For a broad survey on business investment modeling methodologies see *Chirinko (1993)*.
[30] See the appendix for the properties of the neoclassical production function.
[31] Domestic labor $L$ is normalized to unity. Hence all variables are in per capita terms. We also neglect wages coming from labor.
[32] See *Barro and Sala-i Martin (2004)*, pp.152-160.

The price of each unit of capital goods, in real terms, is $(r+\delta)^{\theta}\left(\varepsilon\frac{p_{mk}}{p^{*}}\right)^{1-\theta}$.Where $r$ is the real interest rate, $\varepsilon$ the real exchange rate, $p_{mk}$ the nominal price of imported capital goods, $p^{*}$ the foreign price index and $\theta$ a weighting factor. As $0<\theta<1$, the price of capital is a geometric mean of domestic price of capital, $r+\delta$, and foreign price of capital, expressed in real terms, $\varepsilon\frac{p_{mk}}{p^{*}}$. Similarly, the price of one unit of output, in real terms, is $\left(\varepsilon\frac{p_{xf}}{p^{*}}\right)^{1-\rho}$. Where $p_{xf}$ is the nominal price of exported output and $\rho$ a weighting factor ($0<\rho<1$).

The profits in real terms are:

$$\Pi=\left(\varepsilon\frac{p_{xf}}{p^{*}}\right)^{1-\rho}F(K)-(r+\delta)^{\theta}\left(\varepsilon\frac{p_{mk}}{p^{*}}\right)^{1-\theta}K-C(I) \tag{3.4}$$

As we mentioned earlier, the firm's objective is to choose $I$ at each period to maximize

$$V(0)=\int_{0}^{\infty}e^{-rt}\left\{\left(\varepsilon\frac{p_{xf}}{p^{*}}\right)^{1-\rho}F(K)-(r+\delta)^{\theta}\left(\varepsilon\frac{p_{mk}}{p^{*}}\right)^{1-\theta}K-C(I)\right\}dt \tag{3.5}$$

Subject to:

equation (3.2)

$$K(0)=K_0>0,\ \text{given}$$

To simplify the presentation, we assume as in *Barro and Sala-i Martin (2004)* that $\phi\left(\frac{I}{K}\right)=\frac{\beta}{2}\left(\frac{I}{K}\right)$. Equation (3.3) becomes

$$C(I)=I\left(1+\frac{\beta}{2}\left(\frac{I}{K}\right)\right) \tag{3.3.1}$$

The Hamiltonian of this dynamic optimization problem, in current-value, is

$$\hat{H} = \left(\varepsilon \frac{p_{xf}}{p^*}\right)^{1-\rho} F(K) - (r+\delta)^{\theta} \left(\varepsilon \frac{p_{mk}}{p^*}\right)^{1-\theta} K - I\left(1 + \frac{\beta}{2}\left(\frac{I}{K}\right)\right) + q(I - \delta K) \qquad (3.6)$$

Where $q$ is the current-value shadow price of installed capital in units of contemporaneous output. The maximization conditions are:[33]

Derivative of the Hamiltonian with respect to control variable $I$

$$\hat{H}_I = -1 - \frac{\beta I}{K} + q = 0 \qquad (3.7)$$

Equation of motion for $K$

$$\dot{K} = \frac{\partial \hat{H}}{\partial q}$$

$$\dot{K} = I - \delta K$$

This last expression is equation (3.2). The equation of motion for $q$ is

$$\dot{q} = -\frac{\partial \hat{H}}{\partial K} + rq$$

$$\dot{q} = -\frac{\beta I^2}{2K^2} + q(r+\delta) + (r+\delta)^{\theta} \left(\frac{p_{mk}\varepsilon}{p^*}\right)^{1-\theta} - \left(\frac{p_{xf}\varepsilon}{p^*}\right)^{1-\rho} F'(K) \qquad (3.8)$$

The tranversality condition for the current-value problem can be writing as

$$\lim_{t\to\infty}\left[qKe^{-rt}\right] = 0$$

This condition holds if $q$ and $K$ tend asymptotically towards constants and $r^* > 0$. If we substitute $I$ from equation (3.2) into equation (3.7) we get

[33] See *Chang (1992)*, pp. 161-239.

$$\dot{K} = -\frac{K\left(1+\beta\delta-q\right)}{\beta} \tag{3.9}$$

From this equation, the equilibrium condition, $\dot{K}=0$, for $K$ gives the steady-state value of $q$

$$q^{*} = 1+\beta\delta \tag{3.10}$$

The graphical representation of this equation in a $(K,q)$ space is a horizontal line (see Figure 3.7). Equations (3.2) and (3.9) imply that equation (3.8) can be rewritten as

$$\dot{q} = -\frac{(q-1)^2}{2\beta} + q(r+\delta) + (r+\delta)^{\theta}\left(\frac{p_{mk}\varepsilon}{p^{*}}\right)^{1-\theta} - \left(\frac{p_{xf}\varepsilon}{p^{*}}\right)^{1-\rho} F'(K) \tag{3.11}$$

The equilibrium condition, $\dot{q}=0$, for $q$ gives

$$-\frac{(q-1)^2}{2\beta} + q(r+\delta) + (r+\delta)^{\theta}\left(\frac{p_{mk}\varepsilon}{p^{*}}\right)^{1-\theta} - \left(\frac{p_{xf}\varepsilon}{p^{*}}\right)^{1-\rho} F'(K) = 0 \tag{3.12}$$

If we substitute, $q=q^{*}$, from equation (3.10) into equation (3.12) we get

$$F'\left(K^{*}\right) = \frac{\dfrac{2p_{mk}\left(r+\delta\right)^{\theta}\varepsilon + p^{*}\left(2r\left(1+\beta\delta\right)+\delta\left(2+\beta\delta\right)\right)\left(\dfrac{p_{mk}\varepsilon}{p^{*}}\right)^{\theta}}{2p^{*}}}{\left(\dfrac{p_{mk}\varepsilon}{p^{*}}\right)^{\theta}\left(\dfrac{p_{xf}\varepsilon}{p^{*}}\right)^{1-\rho}} \tag{3.13}$$

In equation (3.12) by applying the implicit-function theorem, the slope of the implicit function, $q(K)$, is

$$\frac{dq}{dK} = \frac{\beta\left(\dfrac{p_{xf}\varepsilon}{p^{*}}\right)^{1-\rho} F''(K)}{1+\beta\left(r+\delta\right)-q} \tag{3.14}$$

By the properties of the neoclassical production function in the appendices, the numerator of this expression is negative. The denominator is positive if the parameters $r$, $\beta$ and $\delta$ are reals, which we suppose, and $q < 1 + \beta(r + \delta)$. This last condition must hold at the steady-state value, $q^*$, because $r^* > 0$. Consequently the implicit function, $q(K)$, is downward sloping (see Figure 3.7). The study of the phase diagram in the appendices indicates that the Figure 3.7 exhibits saddle-path stability with a downward stable arm.

### 3.3.2 Exchange rate pass-through

To analyze the effects of exchange rate on investment we first, make assumptions on the values of $\rho$ and $\theta$ and second, study only the consequences of an exchange rate depreciation, considering that the role of an exchange rate appreciation would be symmetrical. In addition, we assume that $p_{mk}$ , $p_{xf}$ and $p^*$ are constants or equal to one.

**Situation 1:** The firm relies heavily on imported capital ($\theta$ very near 0) and export less output ( $\rho$ very near 1). In that case, exchange rate depreciation (an increase in $\varepsilon$) raises the price of imported capital goods expressed in real terms, this involves a reduction of profits, ceteris-paribus. We can distinguish two cases:

- The producers realize that the depreciation is permanent. The rise in capital costs pushes them to reduce the production permanently. In Figure 3.7, the curve *qe* moves downward because the profits are lower (Figure 3.8). The shadow price of capital $q$ come to the new point corresponding to the given stock of capital on the saddle-path. The two variables $q$ and $K$ rise along the saddle-path toward the new equilibrium $S'$. Given that $\dot{K}$ and $q$ are positively related, the investment shrinks suddenly and then gradually increase. It implies that, a permanent anticipated exchange rate depreciation leads to a temporary decrease in investment.

- The producers realize that the depreciation is temporary. As they know that the profits will come to their original value, $q$ passes first to the point $F$ (Figure 3.9, in the Appendices), then the economy moves towards $G$ on the old saddle-path. Finally, the economy goes down towards point $S$ along the old saddle path. The temporary shock reduces investment but not as much as in the permanent case.

**Situation 2:** The firm relies less on imported capital ($\theta$ very near 1) and export more output ($\rho$ very near 0). Considering this setting, the effects of exchange rate on investment are symmetrical to those presented in situation 1.

The conclusion to draw from this analysis is that the effects of exchange rate on investment are non-linear.

### 3.3.3 The role of volatility

In their study *Campa and Goldberg (1995)* following *Abel and Blanchard (1992)* argued that in the presence of uncertainty, investment is a function of expected per-period profits and the cost of capital. For sake of simplicity, we consider that investment depends only on expected per-period profits.

$$I = \psi\left(E\left(\Pi\left(\varepsilon, p_{xf}, p^{*}, p_{mk}\right)\right)\right) \tag{3.15}$$

Where $E$ is the expectation operator. To examine the impact of exchange rate volatility, we assume as in *Campa and Goldberg (1995)* that the exchange rate is log-normally distributed with mean $\mu$ and variance $\sigma^2$, the distribution of the exchange rate is exogenous to the firm. Then investment is function of $\mu$ and $\sigma^2$.

$$I = \psi\left(E\left(\Pi\left(\mu,\sigma^2\right)\right)\right) = \psi\left(Z\left(\mu,\sigma^2\right)\right) \tag{3.16}$$

Where $Z(\bullet) = E\left(\Pi(\bullet)\right)$. The differentiation of equation (3.16) gives

$$dI = \frac{d\psi}{dZ}\frac{\partial Z\left(\mu,\sigma^2\right)}{\partial\mu}d\mu + \frac{d\psi}{dZ}\frac{\partial Z\left(\mu,\sigma^2\right)}{\partial\sigma^2}d\sigma^2 \tag{3.17}$$

In equation (3.17) if we replace $Z(\bullet)$ by $E\left(\Pi(\bullet)\right)$ we have

$$dI = \frac{\partial E\left(\Pi(\bullet)\right)}{\partial\mu}\psi' d\mu + \frac{\partial E\left(\Pi(\bullet)\right)}{\partial\sigma^2}\psi' d\sigma^2 \tag{3.18}$$

To simplify the presentation, we suppose that the production function is a Cobb- Douglas function

$$Q = F(K) = K^{\alpha} \tag{3.19}$$

In this case the cost function is

$$C(\bullet) = (r+\delta)^{\theta}\left(\varepsilon\frac{p_{mk}}{p^*}\right)^{1-\theta} Q^{\frac{1}{\alpha}} \tag{3.20}$$

The per-period profits are then

$$\Pi = \left(\varepsilon\frac{p_{xf}}{p^*}\right)^{1-\rho} Q - (r+\delta)^{\theta}\left(\varepsilon\frac{p_{mk}}{p^*}\right)^{1-\theta} Q^{\frac{1}{\alpha}} \tag{3.21}$$

Taking expectations[34] of equation (3.21) we have

[34] See the Appendices for details

$$E(\Pi)=\left(\frac{p_{xf}}{p^*}\right)^{1-\rho}\exp\left\{(1-\rho)\mu+\frac{1}{2}(1-\rho)^2\sigma^2\right\}Q \\ -(r+\delta)^{\theta}\exp\left\{(1-\theta)\mu+\frac{1}{2}(1-\theta)^2\sigma^2\right\}\left(\frac{p_{mk}}{p^*}\right)^{1-\theta}Q^{\frac{1}{\alpha}} \tag{3.22}$$

By deriving equation (3.22) with respect to $\mu$ and $\sigma^2$ we get

$$\frac{\partial E(\Pi)}{\partial\mu}=(1-\rho)\exp\left\{(1-\rho)\mu+\frac{1}{2}(1-\rho)^2\sigma^2\right\}\left(\frac{p_{xf}}{p^*}\right)^{1-\rho}Q \\ -(1-\theta)\exp\left\{(1-\theta)\mu+\frac{1}{2}(1-\theta)^2\sigma^2\right\}(r+\delta)^{\theta}\left(\frac{p_{mk}}{p^*}\right)^{1-\theta}Q^{\frac{1}{\alpha}} \tag{3.23}$$

$$\frac{\partial E(\Pi)}{\partial\sigma^2}=\frac{1}{2}(1-\rho)^2\exp\left\{(1-\rho)\mu+\frac{1}{2}(1-\rho)^2\sigma^2\right\}\left(\frac{p_{xf}}{p^*}\right)^{1-\rho}Q \\ -\frac{1}{2}(1-\theta)^2\exp\left\{(1-\theta)\mu+\frac{1}{2}(1-\theta)^2\sigma^2\right\}(r+\delta)^{\theta}\left(\frac{p_{mk}}{p^*}\right)^{1-\theta}Q^{\frac{1}{\alpha}} \tag{3.24}$$

As for the effects of depreciation (appreciation) studied earlier, equation (3.24) shows that the effects of exchange rate volatility on investment are ambiguous. In the first place, exchange rate volatility affects positively profits through domestic and exports sales, in the second place, exchange rate volatility acts negatively on profits through imported capital goods. The effects of exchange rate volatility on investment depend then on which of these effects prevail and on the values of $\theta$ and $\rho$.

## 3.4 Empirical investigation

This section presents the estimation methods, the data and variables, and the results.

### 3.4.1 Estimation Methods

Since our data base is composed of annually data going from 1975 to 2004, we run panel data unit root tests on all variables. Table 3.1 shows that among the five unit root tests, there exist at least one which tells us that each variable is non-stationary.

This outcome led us to apply recent panel data cointegration techniques to estimate a model of the form

$$\frac{I_{it}}{K_{it-1}} = \gamma EV_{it} + \beta' X_{it} + \alpha_i + \varepsilon_{it} \qquad (3.25)$$

Where $\frac{I_{it}}{K_{it-1}}$ is investment $I_{it}$ over lagged capital stock $K_{it-1}$, $EV_{it}$ the exchange rate volatility, $X_{it}$ all other explanatory variables, $\alpha_i$ country individual specific effects, and $\varepsilon_{it}$ the idiosyncratic error. $i$ specifies countries and $t$ the time. To estimate equation (3.25), we use the FMOLS *(Fully Modified Ordinary Least Squares)* estimator developed in panel data context by *Pedroni (1996)* and *Phillips and Moon (1999).*

This estimator was initially introduced in time series context by *Phillips and Hansen (1990).* The advantage of the FMOLS estimator over the OLS estimator[35] is that it deals with possible autocorrelation and heteroskedasticity of the residuals, potential endogeneity of the regressors, takes into account the presence of nuisance parameters and is asymptotically unbiased[36] . Other estimators used for estimations and inferences in panel data cointegration are the DOLS *(Dynamic Ordinary Least Squares)*, *Kao and Chiang (2000)*, *Mark and Sul (1999)*, *Pedroni*

[35] The OLS estimator is super-consistent but is asymptotically biased and is function of nuisance parameters, *Kao and Chen (1995)*, *Pedroni (1996)* and *Kao and Chiang (2000).*
[36] The reader concerned with these problems is invited to look the cited papers. A good survey on recent panel data cointegration is provided by *Baltagi and Kao (2000)* and *Hurlin and Mignon (2006).*

*(2001)*, PMGE *(Pooled Mean Group Estimator)*, *Pesaran, Shin and Smith (1999)*, and the vector error-correction representation, *Breitung (2005)*, *Mark and Sul (2003)*. *Pedroni (1996)* and *Phillips and Moon (1999)* showed that the FMOLS estimator is normally distributed. Analogous results were also obtained by *Kao and Chiang (2000)* for the methods FMOLS and DOLS.

The use of panel data cointegration techniques in estimating equation (3.25) has several advantages. Initially, annual data enable us not to lose information contrary to the method of averages over sub-periods employed in some previous studies. Then, the additions of the cross sectional dimension makes that statistical tests are normally distributed, more powerful and do not depend on the number of regressors as in individual time series.

To test the presence of cointegration in equation (3.25), we utilize *Pedroni (1999)* tests. To explain the tests procedure, we rewrite equation (3.25) in the following manner

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i} x_{1,it} + \beta_{2i} x_{2,it} + \ldots + \beta_{Mi} x_{M,it} + \varepsilon_{it} \tag{3.26}$$

Where $\delta_i$ are time specific effects, $i = 1,\ldots,N$, $t = 1,\ldots,T$ and $m = 1,\ldots,M$. *Pedroni (1999)* compute four within tests and three between tests. If we write the residuals in equation (3.26) as an *AR(1)* process $\hat{\varepsilon}_{it} = \rho_i \hat{\varepsilon}_{it-1} + u_{it}$, the alternatives hypothesis for the tests are formulated in the following manner

- For within tests, the alternative hypothesis is $H_A : \rho_i = \rho < 1 \quad \forall i$
- For between tests, the alternative hypothesis is $H_A : \rho_i < 1 \quad \forall i$

We have seven (4 within and 3 between) tests in *Pedroni (1999)*. See that paper for more details.

## 3.4.2 Data and Variables

To study the effect of volatility on investment, we utilize annually data from 1975 to 2004 of 51 developing countries (23 low-income and 28 middle-income countries)[37]. The data are from World Development Indicators (WDI) 2006, International Financial Statistics (IFS), April, 2006 and CERDI 2006.

In what follows we expose first, the method of the real exchange rate volatility calculation and second, present the other variables used in the study.

Before calculating the exchange rate volatility, we calculate the real exchange rate (with base 100 = 2000) using the following formula

$$REER_{ij} = \prod_{j=1}^{10} \left( \frac{e_j}{e_i} \frac{CPI_i}{CPI_j} \right)^{w_j} \tag{3.27}$$

Where:

$e_j$ is the nominal bilateral exchange rate of partner $j$ compared to the dollar, in foreign-currency (number of dollars for a unit of domestic currency). This series is mainly from the IFS series **rf**;

$e_i$ is the nominal bilateral exchange rate of the country $i$ against the dollar in foreign-currency terms (this series is mainly from the IFS series **rf**);

$CPI_i$: represents the Consumer Price Index (CPI) of country $i$ (generally, IFS line 64 or the growth rate of GDP deflator for countries without *CPI*);

$CPI_j$*:* corresponds to the Consumer Price Index of trade partner $j$ (generally, IFS line 64 or the growth rate of GDP deflator for countries without *CPI*);

[37] The choice of the sample is based on the availability of data.

$w_j$ : stands for trade partner $j$ weight (mean 1999-2003, PCTAS-SITC-Rev.3). Only the first ten partners are taking (CERDI method). The weights used are general trade weights and computed as $\dfrac{\frac{\text{Exports}_j+\text{Imports}_j}{2}}{\sum_{j=1}^{10}\frac{\text{Exports}_j+\text{Imports}_j}{2}}$.

This formula is implemented for each point in time in the period of study considered. But the time subscript is omitted to simplify the presentation. The REER is calculated in foreign-currency terms meaning that an increase of the REER indicates an appreciation and, hence a potential loss of competitiveness.

After calculating the exchange rate, we compute as *Serven (1998)*, *Serven (2002)* and *Bleaney and Greenaway (2001)* the real exchange rate volatility using ARCH family methods. We proceed as such because many ARCH family methods can take account asymmetric chocks effects. We employ two ARCH-Family methods: GARCH (Generalized Autoregressive Conditional Heteroskedasticity), *Bollersev (1986)*, and GARCH-M (GARCH-in-Mean), *Engle, Lilien and Robins (1987)*. The former specification implies symmetric effect of innovations while the second assumes asymmetric impact of good and bad news. The two estimated models, for each country of the sample, are

GARCH(1,1)

$$\begin{aligned} \ln(REER_t)-\ln(REER_{t-1}) &= \beta_0+\varepsilon_t \\ \sigma_t^2 &= \gamma_0+\gamma_1\varepsilon_{t-1}^2+\delta_1\sigma_{t-1}^2 \end{aligned} \tag{3.28}$$

GARCH-M(1,1)

$$\begin{aligned} \ln(REER_t)-\ln(REER_{t-1}) &= \beta_0+\psi\sigma_t^2+\varepsilon_t \\ \sigma_t^2 &= \gamma_0+\gamma_1\varepsilon_{t-1}^2+\delta_1\sigma_{t-1}^2 \end{aligned} \tag{3.29}$$

Where $\varepsilon_t \sim N\left(0,\sigma_t^2\right)$, $\varepsilon_t^2$ is the squared residuals, $\sigma_t^2$ the variance of the regression model's disturbances, $\gamma_0$ and $\gamma_1$ the ARCH parameters, $\delta_1$ the GARCH parameter and $\psi$ the GARCH-M parameter. We compute the exchange rate volatility as the square root of the variance of the regression model's disturbances. In the chapter, the GARCH(1,1) measure of exchange rate volatility is referred to as *REER volatility 1, t* and the GARCH-M(1,1) measure as *REER volatility 2, t*[38].

As dependent variable, we use the ratio of actual investment (WDI constant 2000 US dollars) over lagged capital stock (computed by the perpetual-inventory method using constant 2000 US dollars investment series). Formulating investment this way is known as capacity principle, *Chenery (1952)*[39]. Traditional determinants of investment are considered as control variables: GDP over lagged capital stock, real interest rate, user cost of capital (investment deflator over GDP deflator), inflation, long term debt and the terms of trade. See Table 3.D1 for further details on explanatory variables. Table 3.6 gives summary statistics on all variables.

## 3.4.3 Estimation Results

In this section, we describe first the panel data cointegration tests and second present the estimation results.

[38] The weights used to generate the REER, from which these two measurements come, are respectively: general trade including oil countries, general trade without oil countries.
[39] Other formulations close to this are the capital stock adjustment principle, *Goodwin (1951)* and the flexible accelerator, *Koyck (1954)*.

Table 3.2 illustrates that among the seven tests of *Pedroni (1999)*, there is at least one that shows that we reject the null hypothesis of no cointegration in all 5 equations[40]. This allows us to estimate the panel data cointegration relationships.

As mentioned earlier, panel data cointegration estimators, in particular the FMOLS, deal with possible autocorrelation and heteroskedasticity of the residuals, takes into account the presence of nuisance parameters, are asymptotically unbiased and, more importantly, deal with potential endogeneity of the regressors. Table 3.3 present the results of *Pedroni (1999)* panel data cointegration estimation results.

All five equations illustrates that the real exchange rate volatility is statistically significant and has the expected sign. Regression 1 represents the *capacity principle* model in which we add the real exchange rate volatility. In this model, the REER volatility is negative and marginally significant. The coefficient increases in magnitude and statistical significance when we control for traditional investment determinants, beginning from regression 2. These regressions show that the impact of REER volatility is high. Referring to regression 2, an increase in REER volatility by one standard deviation reduces the ratio of investment to lagged capital stock by an amount approximately equivalent to eight standard deviations. If we take regression 5, the impact become higher because an increase of REER volatility equal to the its interquartile range make the ratio of investment to lagged capital pass from the ninetieth percentile to approximately the tenth percentile, a drop higher than the interquartile range. The absolute value of REER volatility coefficient diminish by more than a half when we introduce long term debt in regression 4, suggesting that the effect of volatility on investment may pass through long term debt. The coefficient of actual GDP over lagged capital stock is positive and highly significant in all regressions. This is in line with *Chenery (1952)* capacity principle which state that an

[40] See Table 3.3 for a list of these equations.

augmentation in capacity usage rise investment. The real interest rate and the user cost of capital have the expected signs and are, generally, statistically significant. Meaning that large costs of capital reduce investment. The other remaining variables have the expected signs and are, generally, statistically significant.

Table 3.4 presents the results of the interaction of the real exchange rate volatility with the variable imports, in the first place, and with the variable exports, in the second place.

In all four regressions, the REER volatility coefficient is negative and significant at 1 percent level. The interaction of REER volatility with imports of goods and services is negative, statistically significant with a high coefficient in absolute value in all first three equations. This suggests that the effect of REER volatility is higher in countries which rely heavily on imports. This outcome corroborates the theoretical prediction of the chapter. In regression 4, the interaction of REER volatility with exports of goods and services has the expected sign. This result implies that, the more an economy exports, the less exchange rate volatility has negative impact on investment. The export threshold for which the marginal impact of REER volatility on investment is nil is 2.54. This value is out of range of exports of goods and services in the sample[41]. Then in our sample, we could consider that the effect of REER volatility on investment is negative in regression 4.

Table 3.5 gives an estimation using an alternative measurement of REER volatility. It also provides regressions on subsamples of low-income and middle-income countries.

As mentioned, the alternative measurement of REER volatility, the GARCH-M(1,1), takes into account asymmetric effects of innovations. Regression 1 in Table 3.5 shows that the impact of the GARCH-M(1,1) measurement is significant and very high. This demonstrates that if we take account asymmetric effects, volatility can have a strong negative impact on investment. The

[41] The minimum of export of goods and services over GDP is 0.0290 and the maximum 1.2441.

coefficients of the REER volatility for regressions on the subsamples of countries are significant and have the expected signs. The absolute value of the coefficient of the REER volatility for low-income countries is larger than that of middle-income countries. Thus the effect of exchange rate volatility on investment is higher in low-income countries than in middle-income countries. This is the case because low income countries are more vulnerable to shocks.

# 3.5 Conclusion

This chapter examines the relation between the exchange rate, its volatility and investment both theoretically and empirically. The theoretical part of the chapter indicates that exchange rate and exchange rate volatility have nonlinear effects on investment. Using new developments on panel data cointegration techniques, we find that real exchange rate volatility has a strong negative impact of investment. An increase in REER volatility by one standard deviation reduces the ratio of investment to lagged capital stock by an amount approximately equivalent to eight standard deviations. The robustness checks illustrates that this negative impact of REER volatility on investment is stable to the use of an alternative measurement of REER volatility and on subsamples of countries (low-income and high-income countries).

Though the results found were informative, some caveats remain. If data on both public and private investment are available, some regressions on these two variables would allow us to compare the effects of REER between these two variables and domestic investment. Some studies on structural change in the context of panel cointegration could also provide helpful information on the impact of REER volatility on investment.

From political economy perspectives, the results illustrate that macroeconomic instability, in particular exchange rate volatility could have negative impacts on investment and that efforts made to reduce them might revive investment and productivity.

As we mentioned previously, chapter 1 provides some arguments about the channels through which the REER or its associated measurements acts on productivity. In the present chapter we explored the investment channel. But we said previously that in addition to investment, the second important channel is through exports or openness in general**.** This is why the next chapter (chapter 4) investigates the effects of both REER volatility and REER misalignment on exports.

# Appendices of Chapter 3

## Properties of the neoclassical production function

1. Constant returns to scale

$F(\lambda K) = \lambda F(K)$ for all $\lambda > 0$

2. Positive and diminishing returns to private inputs

$\partial F / \partial K > 0,\ \partial^2 F / \partial K^2 < 0$

3. Inada conditions

$\lim_{K \to 0} (\partial F / \partial K) = \infty,\ \lim_{K \to \infty} (\partial F / \partial K) = 0$

4. Essentiality

$F(0) = 0$

## Phase diagram study

To study the phase diagram, we consider points either side of the equilibrium lines.

For the *K*-line

- $\dot{K} > 0$ if $q > 1 + \beta\delta$. In Figure 3 this is shown by horizontal arrows pointing to the right.
- $\dot{K} < 0$ if $q < 1 + \beta\delta$. In Figure 3 this is shown by horizontal arrows pointing to the left.

For the *q*-line

- If we start at a point on the $\dot{q}=0$ schedule and increase $K$ a bit, the right-hand side of the expression for $\dot{q}$ in equation (11) increases. Hence $\dot{q}$ is increasing in that region and the arrows point to the north in Figure 3.
- An asymmetric description shows that the arrows point south, in Figure 3, for points to the left of the $\dot{q}=0$ schedule.

**Derivation of equation (3.22)**

The lognormal distribution is

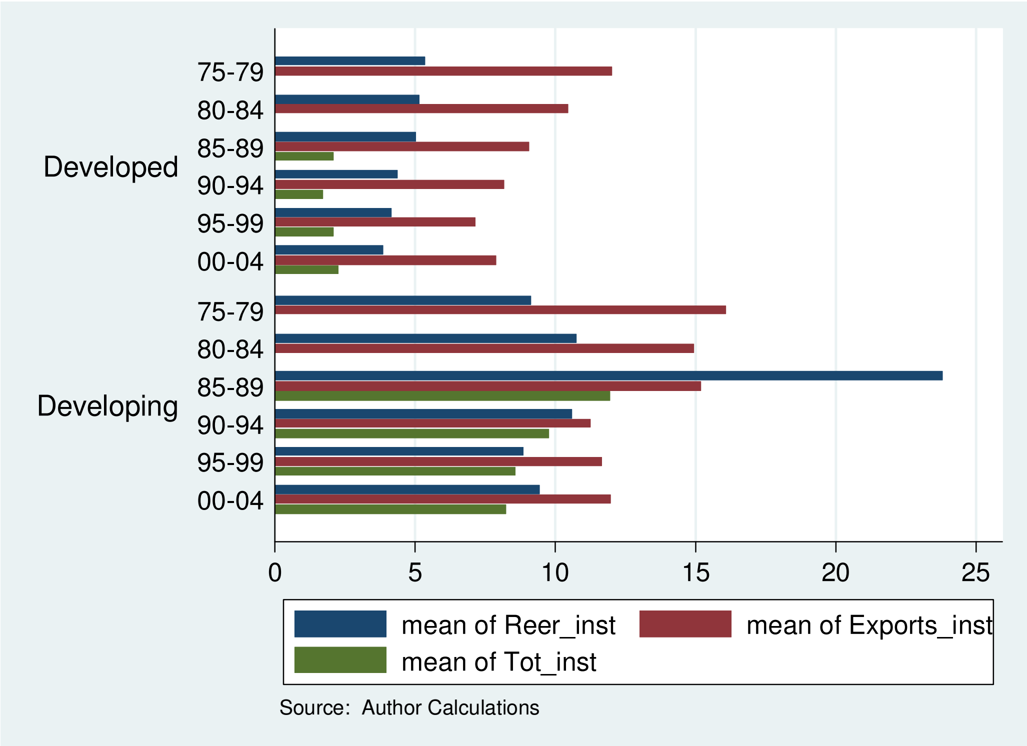
$$f(x)=\begin{cases}\dfrac{1}{\sigma x\sqrt{2\pi}}\exp\left\{-\dfrac{1}{2}\left(\dfrac{\ln x-\mu}{\sigma}\right)^2\right\}, \text{ for } x>0\\ 0, \text{ for } x\leq 0\end{cases}$$

The expectations apply only to the real exchange as it is the only source of uncertainty

$$E(\Pi)=E\left[(\varepsilon)^{1-\rho}\right]\left(\frac{p_{xf}}{p^*}\right)^{1-\rho}Q-(r+\delta)^{\theta}E\left[(\varepsilon)^{1-\theta}\right]\left(\frac{p_{mk}}{p^*}\right)^{1-\theta}Q^{\frac{1}{\alpha}}$$

$$E(\Pi)=\exp\left\{(1-\rho)\mu+\frac{1}{2}(1-\rho)^2\sigma^2\right\}\left(\frac{p_{xf}}{p^*}\right)^{1-\rho}Q$$
$$-(r+\delta)^{\theta}\exp\left\{(1-\theta)\mu+\frac{1}{2}(1-\theta)^2\sigma^2\right\}\left(\frac{p_{mk}}{p^*}\right)^{1-\theta}Q^{\frac{1}{\alpha}}$$

**Figure 3.1:** **Instabilities in Developing and Developed countries (Real Effective Exchange Rate, Exports and Tot)**



**<u>Figure 3.2:</u> Investment over GDP in Developing and Developed countries (1975-2004)**

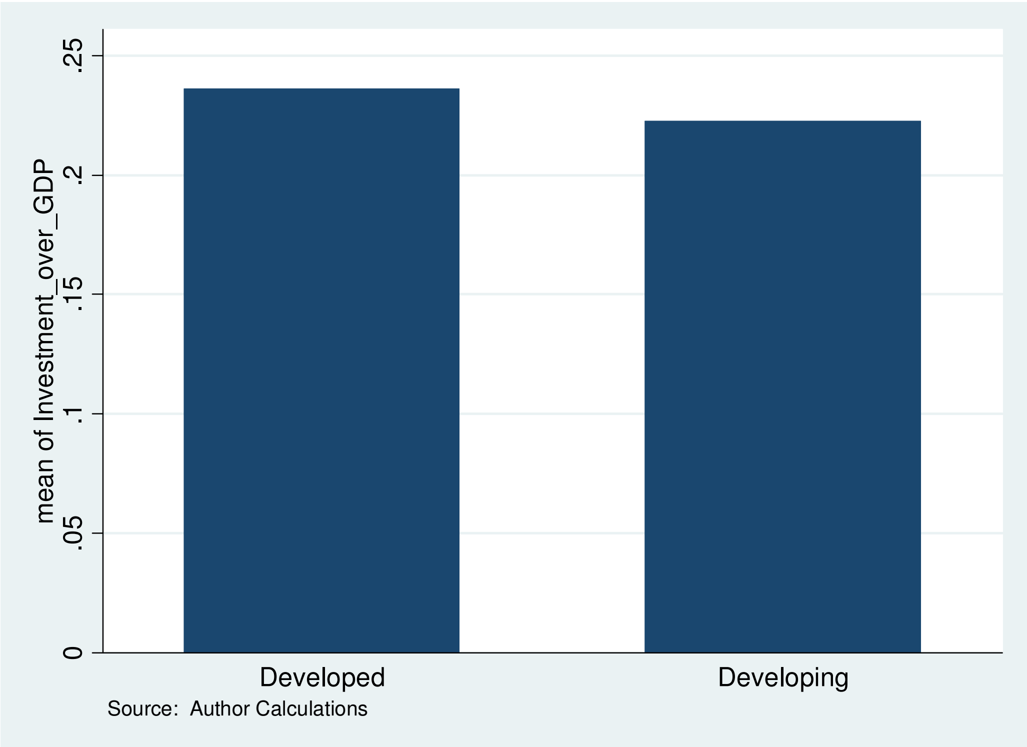
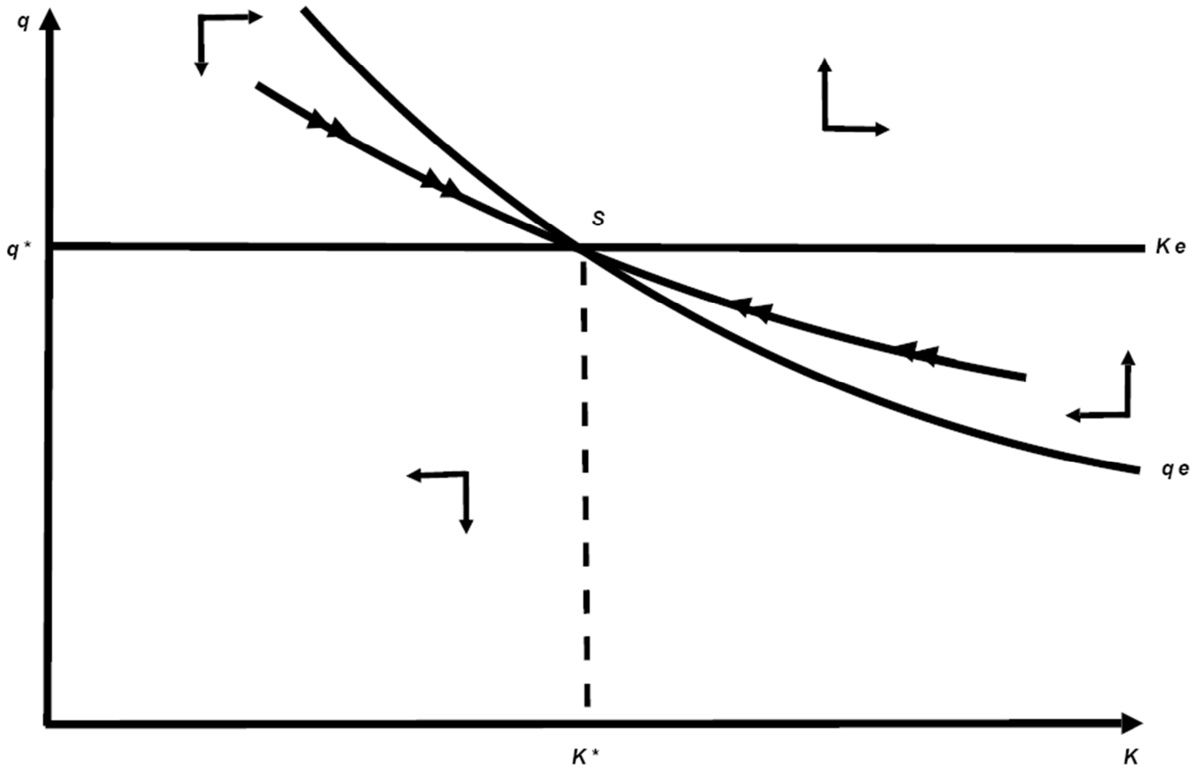
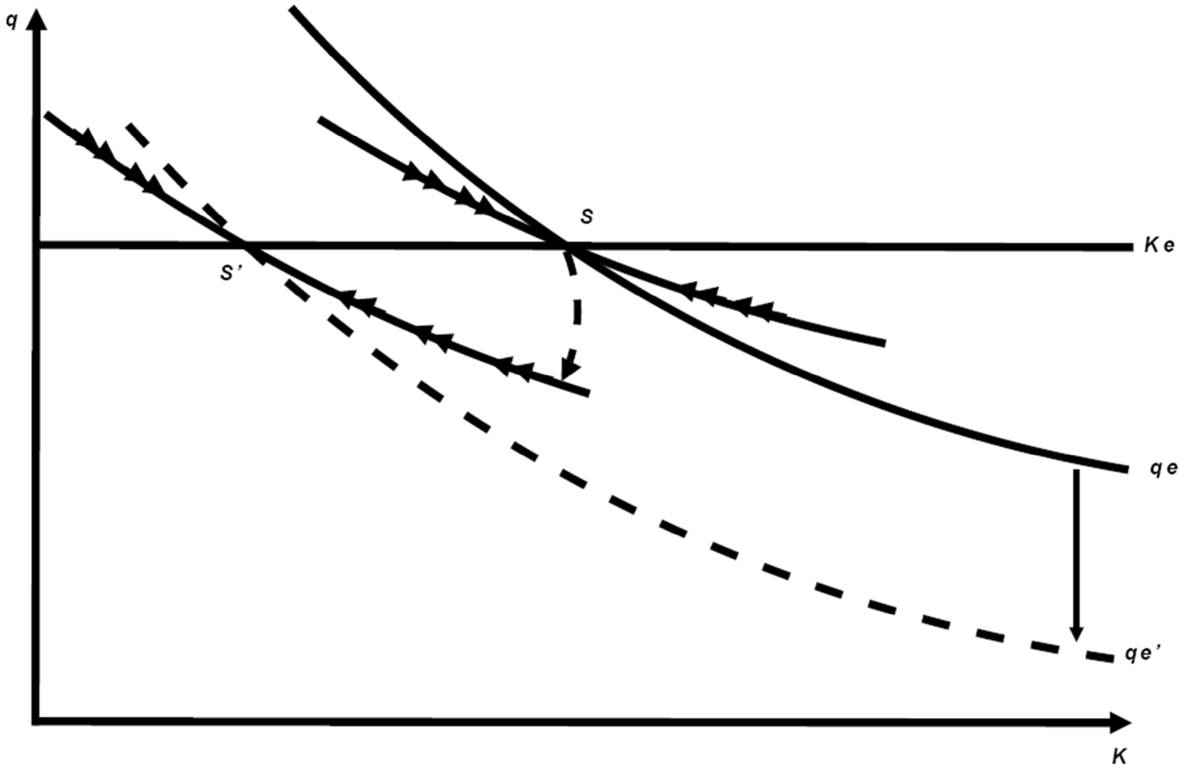


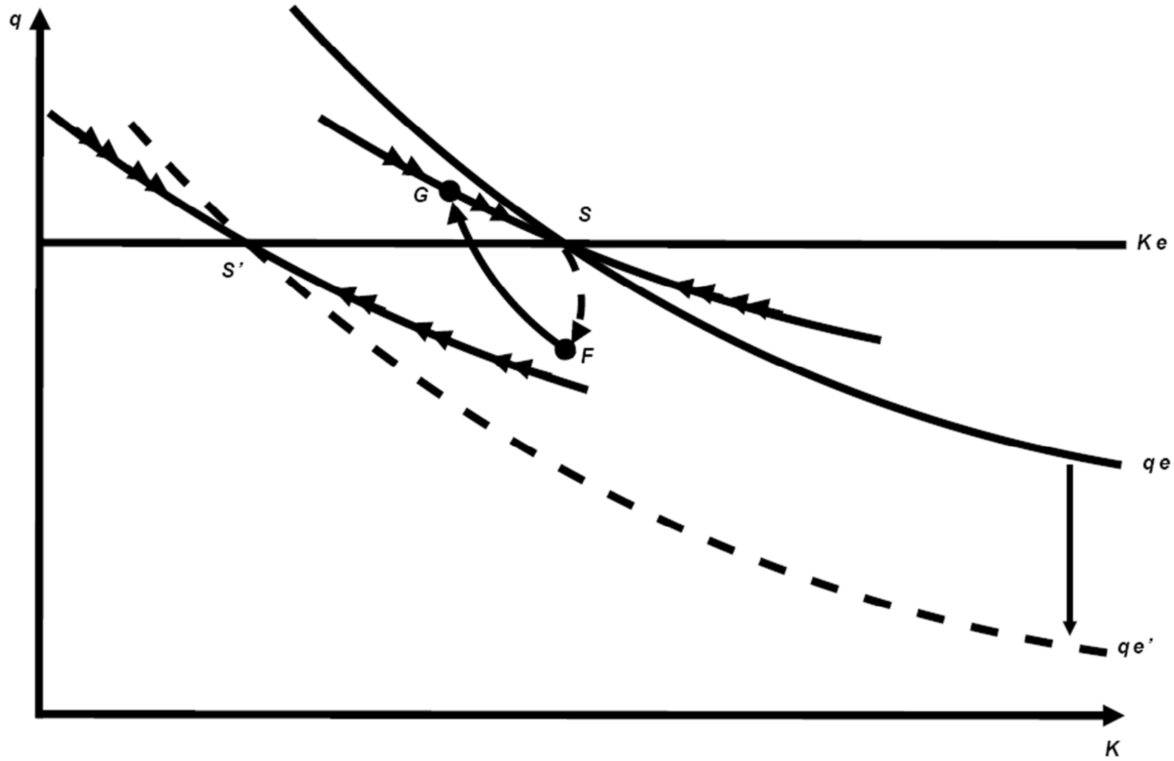
**Figure 3.7: Phase diagram**



**<u>Figure 3.8:</u> Permanente exchange rate depreciation**



**<u>Figure 3.9:</u> Temporary exchange rate depreciation**



# Table 3.1: Panel unit root tests

| Variables | Levin, Lin and Chu t | Breitung t-stat | Im, Pesaran and Shin W-stat | Maddala Wu ADF -Fisher Chi-square | Maddala Wu PP - Fisher Chi-square | Hadri Z-stat |
|---|---|---|---|---|---|---|
| Investment, t / Capital stock, t-1 | 1.2975 | 0.3458 | -1.9590 | 116.8340 | 139.6890 | 9.7625 |
| | (0.9028) | (0.6352) | (0.0251) | (0.1496) | (0.0079 | ( 0.0000) |
| GDP, t / Capital stock, t-1 | 3.3161 | 0.8132 | 0.4463 | 93.9174 | 104.5540 | 12.0348 |
| | ( 0.9995) | (0.7919) | (0.6723) | (0.7035) | (0.4114) | (0.0000) |
| REER volatility 1, t | 3.4882 | -1.2381 | -1.1465 | 122.8660 | 3021.0700 | 6.6479 |
| | (0.9998) | (0.1078) | (0.1258) | (0.0781) | ( 0.0000) | ( 0.0000) |
| Real interest rate, t | -1.5507 | -3.5656 | -2.9037 | 94.2369 | 658.1490 | 13.4941 |
| | ( 0.0605) | (0.0002) | (0.0018) | ( 0.3592) | (0.0000) | ( 0.0000) |
| Investment deflator, t / GDP deflator, t | -0.2080 | -0.6727 | -1.5745 | 108.5020 | 188.7280 | 6.5644 |
| | (0.4176) | (0.2506) | (0.0577) | (0.3112) | (0.0000) | (0.0000) |
| Long term debt, t / GDP, t | 1.6168 | -3.0040 | 2.2875 | 69.1210 | 59.2335 | 9.8184 |
| | (0.9470) | (0.0013) | (0.9889) | (0.9948) | (0.9998) | (0.0000) |
| ln(1+Inflation), t | 1.8531 | -2.9731 | -2.4724 | 134.8430 | 782.8750 | 8.6758 |
| | (0.9681) | (0.0015) | (0.0067) | (0.0163) | (0.0000) | (0.0000) |
| REER volatility 1, t × Imports of GS, t | -0.6414 | -0.5348 | -0.9650 | 103.9010 | 1136.6900 | 6.9685 |
| | ( 0.2606) | (0.2964) | (0.1673) | (0.4290) | (0.0000) | (0.0000) |
| Terms of trade, t | 2.02646 | 1.2532 | -3.5582 | 188.3260 | 211.3420 | 7.5547 |
| | ( 0.9786) | (0.8949) | (0.0002) | (0.0000) | (0.0000) | (0.0000) |
| REER Volatility 2, t | 2.5109 | -0.5354 | -2.7373 | 133.3530 | 2501.2300 | 7.6559 |
| | (0.9940) | (0.2962) | (0.0031) | (0.0202) | (0.0000) | (0.0000) |
| REER volatility 1, t × Exports of GS, t | 0.3174 | -1.0508 | -0.1375 | 98.9928 | 931.1110 | 8.2079 |
| | (0.6245) | (0.1467) | (0.4453) | (0.5659) | (0.0000) | (0.0000) |

Note: The p-values are in parenthesis. All tests include intercepts (fixed effects) and individual trends. For the autocorrelation correction methods, the specified lags are 3 or 4 and Newey-West bandwidth selection using either Barlett, Parzen or Quadratic Spectral kernel depending on the variable and the test type

## Table 3.2: Panel data cointegration tests

| Pedroni Panel Cointegration Tests | | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|---|
| Panel Cointegration tests | panel v-stat | -0.2949 | -2.6656 | -2.9809 | -3.1164 | -3.6536 |
| | panel rho-stat | 0.4283 | 4.1791 | 4.9366 | 4.8765 | 6.5996 |
| | panel pp-stat | -3.1529 | -2.1764 | -3.9206 | -3.0677 | -2.9631 |
| | panel adf-stat | -2.4911 | 2.0490 | 5.6660 | -0.4804 | 0.3043 |
| Group mean cointegration tests | group rho-stat | 2.5166 | 7.3718 | 8.1990 | 8.2804 | 9.6908 |
| | group pp-stat | -1.9672 | -1.6667 | -4.2611 | -2.9673 | -4.6715 |
| | group adf-stat | -1.4405 | 0.3701 | 1.9417 | 0.5910 | 2.8247 |

Note: All reported values are distributed N(0,1) under null of no cointegration

## Table 3.3: Panel data cointegration estimation results

| Dependent Variable: Investment, t / Capital stock, t-1 | | | | | |
|---|---|---|---|---|---|
| Regressors | (1) | (2) | (3) | (4) | (5) |
| GDP, t / Capital stock, t-1 | 0.2361*** | 0.1391*** | 0.2217*** | 0.2194*** | 0.3585*** |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Real interest rate, t | | -0.0121* | -0.1675 | -0.0170*** | -0.5345*** |
| | | (0.0778) | (0.1575) | (0.0006) | (0.0000) |
| Investment deflator, t / GDP deflator, t | | -0.0506*** | -0.0663*** | -0.0257*** | -0.0611*** |
| | | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| REER volatility 1, t | -0.0213* | -0.9431*** | -0.7822*** | -0.3318*** | -1.0195*** |
| | (0.0595) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| ln(1+Inflation), t | | | -0.1615 | | -0.6314*** |
| | | | (0.1989) | | (0.0000) |
| Long term debt, t / GDP, t | | | | -0.0987*** | |
| | | | | (0.0000) | |
| Terms of trade, t | | | | | 0.0695*** |
| | | | | | (0.0000) |

Note: ***, ** and * significant at 1%, 5% and 10% respectively. P-values in brackets

# **<u>Table 3.4:</u> Exchange rate volatility pass-through**

| Dependent Variable: Investment, t / Capital stock, t-1 | | | | |
|---|---|---|---|---|
| Regressors | (1) | (2) | (3) | (4) |
| GDP, t / Capital stock, t-1 | 0.2459*** | 0.2929*** | 0.2933*** | 0.3043*** |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| REER volatility 1, t | -1.4319*** | -0.9161*** | -1.3506*** | -0.5971*** |
| | (0.0016) | (0.0042) | (0.0045) | (0.0049) |
| Imports of GS, t | 0.3553 | 0.3565*** | 0.3242*** | |
| | (0.1328) | (0.0013) | (0.0005) | |
| REER volatility 1, t × Imports of GS, t | -0.1067*** | -0.4744*** | -0.1905*** | |
| | (0.0033) | (0.0044) | (0.0023) | |
| Terms of trade, t | 0.0254*** | | 0.0128*** | |
| | (0.0000) | | (0.0000) | |
| Investment deflator, t / GDP deflator, t | | -0.0525*** | -0.0498*** | -0.0421*** |
| | | (0.0000) | (0.0000) | (0.0000) |
| ln(1+Inflation), t | | 0.0073 | 0.0066 | 0.0118 |
| | | (0.4298) | (0.3045) | (0.1891) |
| Exports of GS, t | | | | 0.0115** |
| | | | | (0.0220) |
| REER volatility 1, t × Exports of GS, t | | | | 0.2349** |
| | | | | (0.0117) |

Note: ***, ** and * significant at 1%, 5% and 10% respectively. P-values in brackets

## <u>Table 3.5:</u> Estimation results using an alternative measurement of real effective exchange rate volatility and on sub-samples of countries

| Dependent Variable: Investment, t / Capital stock, t-1 | | | |
|---|---|---|---|
| | Full sample | Middle-Income Countries | Low-Income Countries |
| Regressors | (2) | (2) | (5) |
| GDP, t / Capital stock, t-1 | 0.4308*** | 0.3096*** | 0.4067*** |
| | (0.0000) | (0.0000) | (0.0000) |
| Real interest rate, t | -0.0119*** | -0.0411*** | -1.2375*** |
| | (0.0000) | (0.0000) | (0.0000) |
| Investment deflator, t / GDP deflator, t | -0.0827*** | -0.0463*** | -0.1172*** |
| | (0.0000) | (0.0000) | (0.0000) |
| REER volatility 1, t | | -0.0489*** | -1.8454*** |
| | | (0.0040) | (0.0000) |
| REER volatility 2, t | -7.7435*** | | |
| | (0.0000) | | |
| ln(1+Inflation), t | | | -1.3942*** |
| | | | (0.0000) |
| Terms of trade, t | | | 0.0578*** |
| | | | (0.0000) |

Note: ***, ** and * significant at 1%, 5% and 10% respectively. P-values in brackets

# **<u>Table 3.D1:</u> Explanatory Variables (definitions, expected sign and source)**

| Variables | Definitions, Expected Sign and References | Data Source |
|---|---|---|
| GDP, t / Capital stock, t-1 | Actual GDP over lagged capital stock, capacity principle, *Chenery (1952)*. Based on this theory and the related ones (capital stock adjustment principle, *Goodwin (1951)* and flexible accelerator, *Koyck (1954)*), we expect this variable to have a positive sign. This variable is included to take account inertia problems since we cannot include the lagged dependent variable | WDI 2006 |
| Real interest rate, t | We expect real interest rates to have a negative effect | WDI 2006 |
| Investment deflator, t / GDP deflator, t | It is a proxy for the user cost of capital. It should exert a negative impact on investment, *Serven (2002)* | WDI 2006 |
| REER volatility 1, t × Imports of GS, t | Real Effective Exchange Rate times Import of goods and services over GDP. The theoretical part of the paper suggests that exchange rate volatility can affects investment through imported capital stock. We introduce imports of goods and services as a proxy for imported capital stock. We expect the variable Real effective exchange rate volatility × Imports of goods and services over GDP to have a negative effect | WDI 2006 |
| REER volatility 1, t × Exports of GS, t | Real Effective Exchange Rate times Exports of goods and services over GDP. The theoretical part of the paper suggests that exchange rate can affects investment through export sales. We expect the variable Real effective exchange rate volatility × Export of goods and services over GDP to have a positive impact | WDI 2006 |
| Long term debt, t / GDP, t | Long term debt over GDP. It should have a negative effect | WDI 2006 |
| Terms of trade, t | Prices of exports over prices of imports. This variable should exert a positive effect | WDI 2006 |
| ln(1+Inflation), t | Natural logarithm of 1 plus annual inflation rate. This variable is expected to have a negative sign | WDI 2006 |

## **Table 3.6:** Summary statistics on variables

| Variables | Observations | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Investment, t / Capital stock, t-1 | 1472 | 0.0725 | 0.0296 | -0.0050 | 0.1994 |
| GDP, t / Capital stock, t-1 | 1475 | 0.3599 | 0.1928 | 0.0584 | 1.6920 |
| Real interest rate, t | 1087 | 0.0767 | 0.2799 | -0.9781 | 7.8980 |
| Investment deflator, t / GDP deflator, t | 1523 | 1.0586 | 0.3474 | 0.1198 | 3.4958 |
| REER volatility 1, t | 1499 | 0.1323 | 0.2534 | 0.0000 | 6.8452 |
| REER volatility 1, t × Imports of GS, t | 1498 | 0.0437 | 0.1409 | 0.0000 | 4.4626 |
| ln(1+Inflation), t | 1530 | 0.1733 | 0.3717 | -0.2763 | 4.7749 |
| Long term debt, t / GDP, t | 1517 | 0.6140 | 0.6023 | 0.0233 | 8.2349 |
| Terms of trade, t | 1518 | 1.0853 | 0.3759 | 0.3213 | 6.0800 |
| REER volatility 2, t | 1499 | 0.1213 | 0.1364 | 0.0000 | 2.2887 |
| REER volatility 1, t × Exports of GS, t | 1498 | 0.0338 | 0.0698 | 0.0000 | 2.2272 |

# **Table 3.7:** List of 51 countries

| Low Income countries | | |
|---|---|---|
| N° | Word Bank Code | Countries |
| 1 | BDI | Burundi |
| 2 | BEN | Benin |
| 3 | BFA | Burkina Faso |
| 4 | BGD | Bangladesh |
| 5 | CIV | Cote d'Ivoire |
| 6 | CMR | Cameroon |
| 7 | COG | Congo, Rep. |
| 8 | GHA | Ghana |
| 9 | GMB | Gambia, The |
| 10 | GNB | Guinea-Bissau |
| 11 | IND | India |
| 12 | KEN | Kenya |
| 13 | LSO | Lesotho |
| 14 | MDG | Madagascar |
| 15 | MLI | Mali |
| 16 | MRT | Mauritania |
| 17 | MWI | Malawi |
| 18 | NIC | Nicaragua |
| 19 | RWA | Rwanda |
| 20 | SEN | Senegal |
| 21 | TGO | Togo |
| 22 | ZMB | Zambia |
| 23 | ZWE | Zimbabwe |

| Middle Income countries | | |
|---|---|---|
| N° | Word Bank Code | Countries |
| 1 | ARG | Argentina |
| 2 | BOL | Bolivia |
| 3 | CHL | Chile |
| 4 | CHN | China |
| 5 | COL | Colombia |
| 6 | CRI | Costa Rica |
| 7 | DOM | Dominican Republic |
| 8 | DZA | Algeria |
| 9 | ECU | Ecuador |
| 10 | EGY | Egypt, Arab Rep. |
| 11 | GAB | Gabon |
| 12 | GTM | Guatemala |
| 13 | HND | Honduras |
| 14 | HUN | Hungary |
| 15 | IDN | Indonesia |
| 16 | LKA | Sri Lanka |
| 17 | MAR | Morocco |
| 18 | MEX | Mexico |
| 19 | MYS | Malaysia |
| 20 | PER | Peru |
| 21 | PHL | Philippines |
| 22 | PRY | Paraguay |
| 23 | SWZ | Swaziland |
| 24 | THA | Thailand |
| 25 | TTO | Trinidad and Tobago |
| 26 | TUN | Tunisia |
| 27 | URY | Uruguay |
| 28 | VEN | Venezuela, RB |

Note: This subdivision is from the Word Development Indicators 2006 classification based on countries 2004 GNI per capita: Low Income Countries (GNI/per capita ≤ US \$825); Middle Income Countries (US \$826 ≤ GNI per capita ≤ US \$10065).

# Chapter 4:

# The Effects of Real Exchange Rate Misalignment and Real Exchange Rate Volatility on Exports

# 4.1 Introduction

Theoretically, real effective exchange rate (REER) misalignment has a negative effect on economic performance. In fact, it reduces the export of tradable goods and the profitability of production. REER misalignment deteriorates domestic investment and foreign direct investment, consequently growth, by increasing uncertainty. REER misalignment leads also to a reduction in economic efficiency and a misallocation of resources (*Edwards (1988a)*, *Cottani, et al. (1990)* and *Ghura and Grennes (1993))*. Studies have also shown that undervaluation can improve growth. *Levy-Yeyati and Sturzenegger (2007)* state that undervaluation increases output and productivity through an expansion of savings and capital accumulation. *Rodrik (2009)* illustrates that undervaluation rises the profitability of the tradable sector, and leads to an extension of the share of tradable in domestic value added. Larger profitability encourages investment in the tradable sector and helps economic growth. *Korinek and Serven (2010)* illustrates that real exchange rate undervaluation can increase growth through learning-by-doing externalities in the tradable sector.

Real effective exchange rate (REER) volatility has also a negative impact on economic performance. In fact, higher REER instability raises uncertainty on the profitability of producing tradable goods and of long-run investments. Higher REER volatility sends confusing signals to economic agents (*Grobar (1993), Cushman (1993)* and *Gagnon (1993)).* Some authors, like *Aghion et al. (2009),* have argued that the impact of exchange rate volatility on economic performance is function of the level of financial development. Others states that the effect of exchange rate variability on economic performance depends on the complementarity between macroeconomic stability and political factors *(Eichengreen (2008)).*

Many studies have investigated the empirical link between exchange rate misalignment, REER volatility and economic performance in general and between REER misalignment and exports in particular. *Cottani et al. (1990), Razin and Collins (1997),* and *Aghion et al*. (2009) show that there exists a negative correlation between REER volatility or REER misalignment and economic performance. For the link REER misalignment-export, using a panel data of 53 countries *Nabli and Véganzonès-Varoudakis (2002)* found a negative relationship. The same results were found by *Jongwanich (2009)* for a sample of Asian developing countries. *Sekkat and Varoudakis (2000)* found that REER volatility does not have a systematic negative impact on manufactured export while REER misalignment exerts a significant negative influence on export for a panel of Sub-Saharan African countries. *Jian (2007)* also found that exchange rate misalignment has a negative influence on China's export.

This chapter fits in these researches of the links between the REER misalignment, REER volatility and economic performance. It specifically analyzes the relationship between exchange rate misalignment, REER volatility and total exports. It distinguishes itself by using panel data cointegration techniques and a measurement of REER volatility which have not been used in previous works. It also employs a measurement of REER misalignment that is based on panel data cointegration techniques. The sample studied contains 42 developing countries from 1975 to 2004. We use panel data cointegration techniques because our time span is too large: 30 years. This raises the question of the existence of potential unit root in the variables studied and leads to the issue of cointegration. The application of panel data cointegration techniques has several advantages. Initially, annual data enable us not to lose information contrary to the method of averages over sub-periods. Then, the addition of the cross sectional dimension makes that statistical tests are normally distributed, more powerful and do not depend on the number of regressors in the estimation as in individual time series. Among the panel data cointegration techniques, we utilize *Pesaran et al. (1999) Pooled Mean Group Estimation of Dynamic Heterogeneous Panels* estimator. The microeconomic panel data methods: random effects, fixed effects, and GMM oblige the parameters (coefficients and error variances) to be identical across groups, but the intercept can vary between groups. GMM estimation of dynamic panel models could lead to inconsistent and misleading long-term coefficients when the period is long. *Pesaran et al. (1999)* suggest a transitional estimator that permits the short-term parameters to differ between groups while imposing equality of the long-run coefficients.

The chapter is organized as follow: section 4.2 provides some stylized facts on the associated measurements of real effective exchange rate and exports, section 4.3 presents the econometrics models and estimations methods, section 4.4 analyzes the data and variables, section 4.5 shows how the variables of interests are measured, sections 4.6 and 4.7 deal with the panel data tests and the estimation results respectively. Section 4.8 carry out some robustness analysis and the last section concludes.

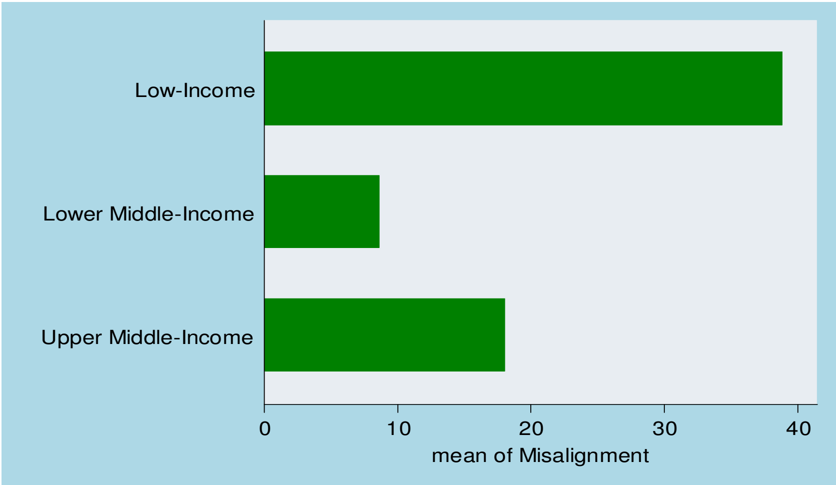
## 4.2 Some Stylized Facts on the Associated Measurements of Real Effective Exchange Rate and Exports

In this section we give some stylized facts on the associated measurements of REER and exports.

- ***Distribution of Real Effective Exchange Rate Misalignment over Income Groups:***

Figure 4.1 provides the distribution of REER misalignment by Income category for the overall period 1975-2004. We observe that REER misalignment is greater in Low-Income countries than any other group. Misalignment in this group is twice than that of Upper Middle-Income category and nearly the triple of the misalignment in Lower Middle-Income countries. This latter group knows the lowest misalignment than all Income categories.

**<u>Figure 4.1:</u> Distribution of Real Effective Exchange Rate Misalignment over Income Groups**

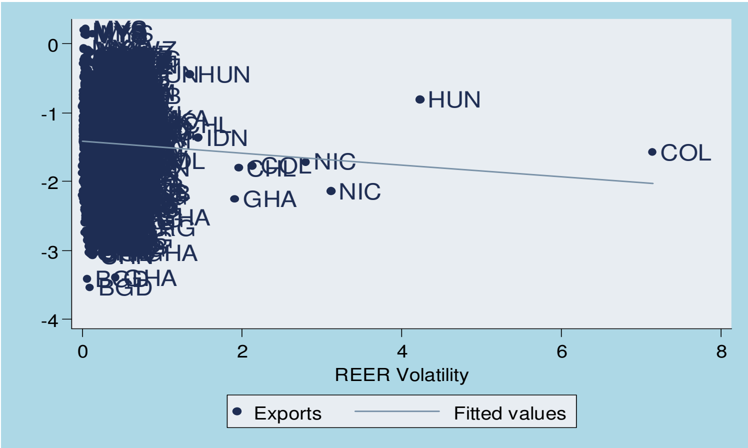



Note: The period of study is 1975-2004. Source: Author's calculations.

- ***Exports in Function of the Real Effective Exchange Rate Volatility:***

In Figure 4.2, we notice that there exists a negative connection between REER volatility and exports. Thus economies with large REER volatilities tend to enjoy lower exports. The results illustrate that REER volatility could be harmful to exports.

**<u>Figure 4.2:</u> Exports in Function of the Real Effective Exchange Rate Volatility**

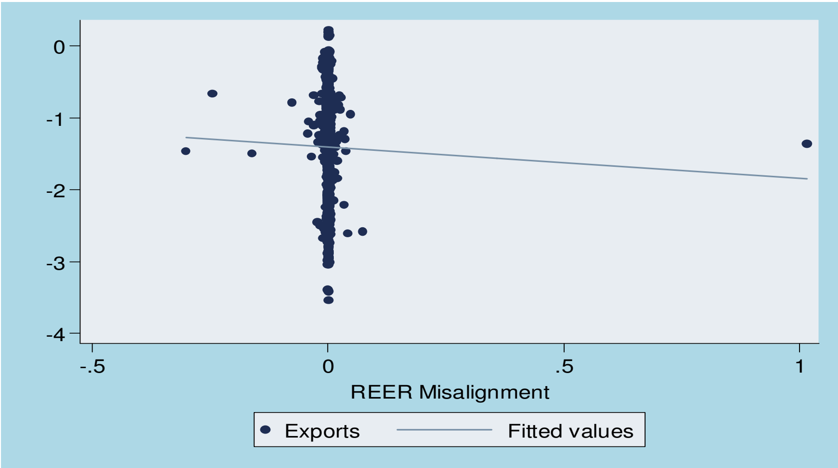



Note: Exports are Log exports to GDP. The period of study is 1975-2004. Source: Author's calculations.

- ***Exports in Function of the Real Effective Exchange Rate Misalignment:***

As in Figure 4.2, Figure 4.3 illustrates that there exist a negative association between the REER misalignment and exports. Thus economies with greater REER misalignment seem to have inferior Exports. Figure 4.2 also demonstrates that REER volatility is more harmful to Exports than misalignment since the slope of Figure 4.2 is slightly larger in magnitude than that of Figure 4.3. This result is also confirmed in the empirical results in this chapter.

**Figure 4.3: Exports in Function of the Real Effective Exchange Rate Misalignment**

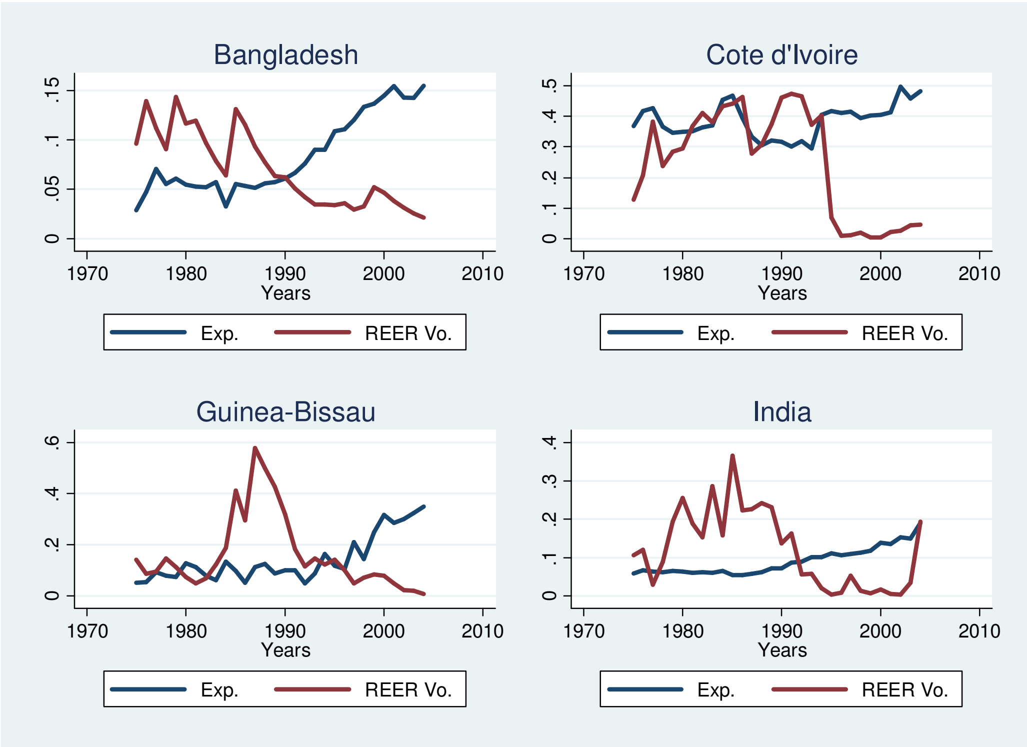



Note: Exports are Log exports to GDP. The REER misalignment is rescaled in order to obtain an adequate graph. The period of study is 1975-2004. Source: Author's calculations.

- ***Evolution of Real Effective Exchange Rate Volatility and Exports by Country:***

Figure 4.4 provides the evolution of REER volatility and exports for 4 countries. The graphs, generally, illustrates that exports and REER volatility move in opposite ways. For Bangladesh, REER volatility was very high prior to 1990. Exports were also low in this country before this date. Contrarily, exports started to increase sharply after 1990 when REER volatility dropped drastically. In Côte d'Ivoire and Guinea-Bissau, exports started to rise when REER volatility dropped severely after the devaluation of the CFA Franc in 1994. Exports were very low in India when REER volatility was high before the beginning of 1990s. But exports started to augment when REER volatility suddenly dropped in the 1990s, although REER volatility started to increase at the commencement of 2000s. The results in this figure corroborate those found in Figure 4.2 that REER volatility and exports are negatively correlated.

**<u>Figure 4.4:</u> Evolution of Real Effective Exchange Rate Volatility and Exports by Country**

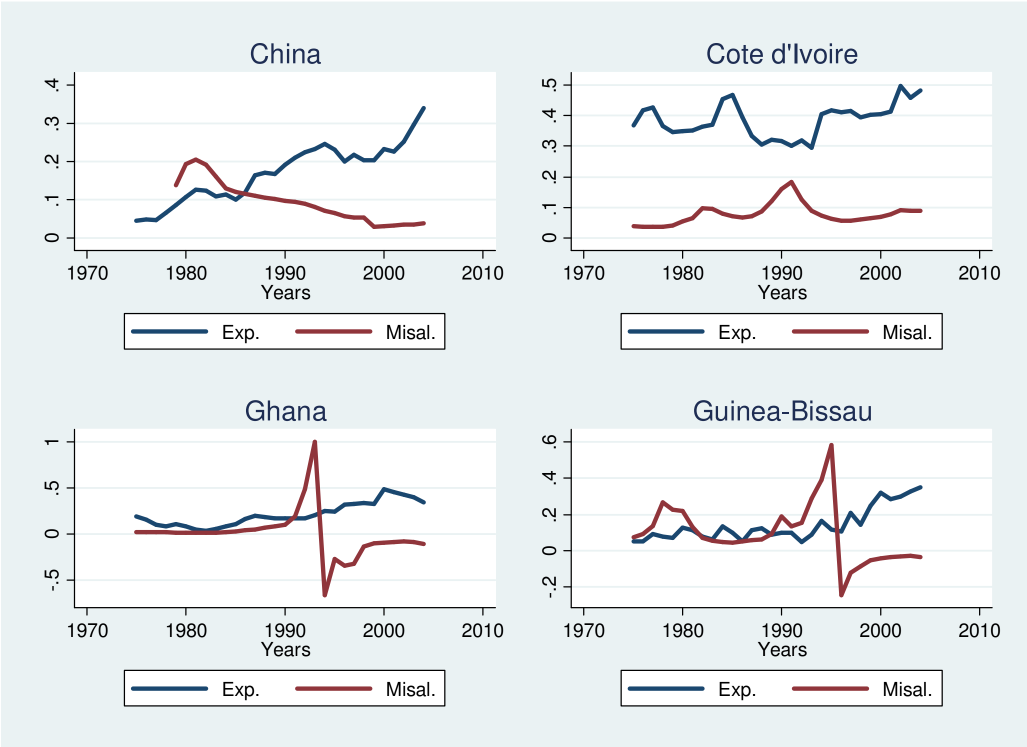



Note: Exports are exports over GDP. The period of study is 1975-2004. Source: Author's calculations.

- ***Evolution of Real Effective Exchange Rate Misalignment and Exports by Country:***

Figure 4.5 gives the evolution of REER misalignment and exports for 4 countries. The figure demonstrates that, in general, REER misalignment and exports evolve in opposite directions. In China, exports started to increase when REER misalignment suddenly dropped in middle of 1980s. The same thing happened in Côte d'Ivoire but at the beginning of 1990s. In Ghana and Guinea-Bissau also exports started to augment when REER misalignment fell drastically at the middle of 1990s. The results in this figure corroborate those found in Figure 4.3 that REER misalignment and exports are negatively linked.

**<u>Figure 4.5:</u> Evolution of Real Effective Exchange Rate Misalignment and Exports by Country**




Note: Exports are exports over GDP. The REER misalignment is rescaled in order to obtain an adequate graph. The period of study is 1975-2004.

Source: Author's calculations.

The graphs exposed in this section illuminate some key results concerning the main variables utilized in this chapter. REER volatility affects exports negatively. We also note that exports and REER misalignment are negatively associated. It is therefore important to examine these correlations observed in these stylized facts more rigorously. This is what we examine in the remaining sections.

# 4.3 Econometrics models and estimations methods

To estimate the effects of exchange rate misalignment and REER volatility on total exports, the method of *Pooled Mean Group Estimation of Dynamic Heterogeneous Panels* of *Pesaran et al. (1999)* is applied. In this model, the long-run variation of export and other regressors are supposed to be identical for countries but short-run movements are expected to be specific to each country. The estimated model is an (ARDL)$(p, q_1, \ldots, q_k)$ representation of the form:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{4.1}$$

Where $i = 1, 2, \ldots, N$ is the number of groups; $t = 1, 2, \ldots, T$ is the number of periods; $X_{it}$ is the $k \times 1$ vector of regressors; $\delta_{ij}$ are the $k \times 1$ coefficient vectors; $\lambda_{ij}$ are scalars and $\mu_i$ is the fixed effects.

Equation (4.1) can be rewritten as error correction model of the form:

$$\Delta y_{it} = \phi_i \left( y_{i,t-1} - \theta'_i X_{it} \right) + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-1} + \sum_{j=0}^{q-1} \delta'^*_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{4.2}$$

Where $\phi_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right)$; $\theta_i = \sum_{j=0}^{q} \delta_{ij} / \left(1 - \sum_{k} \lambda_{ik}\right)$; $\lambda^*_{ij} = -\sum_{m=j+1}^{p} \lambda_{im}$ $j = 1, 2, \ldots, p-1$ and $\delta^*_{ij} = -\sum_{m=j+1}^{q} \delta_{im}$ $j = 1, 2, \ldots, q-1$.

The parameter $\phi_i$ is the error correction term. This parameter is supposed to be significantly negative since it is assumed that the variables return to a long-term equilibrium. The long-run relationships between the variables are in the vector $\theta'_i$. To estimate equation (4.2) *Pesaran et al. (1999)* propose a PMG estimator. This estimator constrains the long-term coefficients to be equal through the groups but forces short-term coefficients and error variances to be different through the groups. *Pesaran et al. (1999)* use the maximum likelihood method to estimate the parameters in equation (4.2) given that this equation is nonlinear. The log-likelihood function is given by:

$$l_T(\theta', \varphi', \sigma') = -\frac{T}{2}\sum_{i=1}^{N} \ln\left(2\pi\sigma_i^2\right) - \frac{1}{2}\sum_{i=1}^{N}\frac{1}{\sigma_i^2}\left\{\Delta y_i - \phi_i\xi_i(\theta)\right\}' H_i \left\{\Delta y_i - \phi_i\xi_i(\theta)\right\} \tag{4.3}$$

Where $i = 1,...,N$; $\xi_i(\theta) = y_{i,t-1} - X_i\theta_i$; $H_i = I_T - W_i\left(W_i' W_i\right)W_i$, $I_T$ is an identity matrix of order $T$ and $W_i = \left(\Delta y_{i,t-1},...,\Delta y_{i,t-p+1}, \Delta X_i, \Delta X_{i,t-1},...,\Delta X_{i,t-q+1}\right)$.

The estimated long-run relationship between REER misalignment, REER volatility, the control variables and exports is:

$$\begin{aligned} Log(EXPGDP_{it}) = \theta_0 + \theta_1 MISAL_{it} + \theta_2 RERVOL_{it} + \theta_3 Log(MVADGDP_{it}) + \theta_4 Log(GDPTP_{it}) + \\ \theta_5 Log(TOT_{it}) + \theta_6 Log(RGDP_{it}) + \theta_7 Log(INVGDP_{it}) + \upsilon_{it} \end{aligned} \tag{4.4}$$

Where $\theta_i$ are the long-term parameters, $Log(EXPGDP_{it})$ is Log Exports to GDP, $MISAL_{it}$ is REER misalignment, $RERVOL_{it}$ is REER volatility, $Log(MVADGDP_{it})$ Log Manufactured value added to GDP, $Log(GDPTP_{it})$ Log GDP of trade partners, $Log(TOT_{it})$ Log Terms of trade, $Log(RGDP_{it})$ Log Real GDP and $Log(INVGDP_{it})$ Log Investment to GDP. Table 4.1 gives the definition, expected signs and sources of all variables of the study and Table 4.2 shows the summary statistics on the variables. If we assume that all variables in equation (4.4) are *I(1)* and cointegrated then $\upsilon_{it}$ is *I(0).* The error correction representation of equation (4.4) is given by:

$$\begin{aligned}\Delta Log(EXPGDP_{it}) = \phi_i[&Log(EXPGDP_{it-1}) - \theta_0 - \theta_1 MISAL_{it} - \theta_2 RERVOL_{it} - \theta_3 Log(MVADGDP_{it}) \\ &- \theta_4 Log(GDPTP_{it}) - \theta_5 Log(TOT_{it}) - \theta_6 Log(RGDP_{it}) - \theta_7 Log(INVGDP_{it})] \\ &+ \delta_{1i}\Delta MISAL_{it} + \delta_{2i}\Delta RERVOL_{it} + \delta_{3i}\Delta Log(MVADGDP_{it}) + \delta_{4i}\Delta Log(GDPTP_{it}) \\ &+ \delta_{5i}\Delta Log(TOT_{it}) + \delta_{6i}\Delta Log(RGDP_{it}) + \delta_{7i}\Delta Log(INVGDP_{it}) + \varepsilon_{it} \qquad (4.5)\end{aligned}$$

The parameter $\phi_i$ is the error-correcting speed of adjustment term. As mentioned above, we expect this parameter to be significantly negative implying that variables return to a long-run equilibrium.

## 4.4 Data and Variables

To study the effect of REER misalignment and REER volatility on exports, we utilize annual data from 1975 to 2004 for 42 developing countries. The data are from World Development Indicators (WDI) 2006, International Financial Statistics (IFS), April, 2006 and Centre D'études Et De Recherches Sur Le Développement International (CERDI) 2006. Table 4.3 gives the list of all countries used in the study.

The REER is calculated according to the following formula:

$$RER_{ij} = \prod_{j=1}^{10} \left( NBER_{ij} \frac{CPI_i}{CPI_j} \right)^{\omega j} \qquad (4.6)$$

Where:

$NBER_{ij}$ : is the nominal bilateral exchange rate of trade partner $j$ relative to country $i$

$CPI_i$ : represents the consumer price index of country $i$ (IFS line 64). When the country $CPI$ is missing, the growth rate of the GDP deflator is used to fill the data;

$CPI_j$: corresponds to the consumer price index of trade partner $j$ (IFS line 64). When the country $CPI$ is missing, the growth rate of the GDP deflator is used to fill the data;

$\omega_j$: stands for trade partner $j$ weight (mean 1999-2003, PCTAS-SITC-Rev.3). Only the first ten partners are taking (CERDI method). These first ten partners constitute approximately 70% of trade weights. The weights used to generate the REER are general trade *(Exports + Imports)* excluding oil countries. Weights are computed at the end of the period of study in order to focus on the competitiveness of the most recent years.

An increase of the REER indicates an appreciation and, hence a potential loss of competitiveness.

The sample of study includes 42 developing countries for the following reasons. First, we wanted to limit our analysis to developing countries only, since there are few papers studying the relationship between the associated measures of REER and exports on non-advanced countries. Second, we employ the asymmetric EGARCH (1, 1)[42] method to obtain our measurement of REER volatility. As is well known, it is extremely difficult to obtain convergence of the log-likelihood function with ARCH family methods in general and with asymmetric EGARCH (1, 1) techniques in particular. Hence we had to retain only countries for which we had convergence. The sample of 42 countries may seem small but this is not the case. In fact if we take into account the time dimension and remember that we have a panel data of 42 countries with 30 years, the total number of observations is 1260. This is well above 30 which is the number of observations generally needed for inference.

[42] See below for more details.

## 4.5 Measurement of variables of interest

In this section, we will present how the variables of interest are calculated.

### 4.5.1 Measurement of Real Effective Exchange Rate Misalignment

Before calculating the REER misalignment, we first compute the equilibrium real effective exchange rate (EREER). The economic literature on exchange rate states that REER is affected by its determinants called "fundamentals" *(Williamson (1994), Edwards (1998))*. Following *Edwards (1988b)* the EREER is the REER that allows attaining both external and internal equilibrium for given viable equilibrium values of the fundamentals. On the one hand, external equilibrium is satisfied when the values of present and future current account balances are harmonious with long term bearable capitals flows. On the other hand, internal equilibrium is attained when the non-tradable goods market is balanced for the present and future periods. As for REER misalignment it is defined as inexorable departures of the actual REER from its equilibrium rate. We use the PMG estimator to estimate the relationship between REER and its fundamentals. The long-run estimated equation is:

$$Log(REER_{it}) = \theta_0 + \theta_1 Log(TOT_{it}) + \theta_2 Log(GDPCAP_{it}) + \theta_3 Log(OPEN_{it}) + \upsilon_{it} \qquad (4.7)$$

Where $Log(REER_{it})$ is the logarithm of real effective exchange rate, $Log(TOT_{it})$ the log of terms of trade, $Log(GDPCAP_{it})$ the log of real GDP per capita and $Log(OPEN_{it})$ is the log of export and import over GDP.

We expect that a rise in terms of trade ameliorates trade balance, the income effect dominating the substitution effect, hence $\theta_1$ is expected to be positive. GDP per capita captures the *Balassa-Samuelson* effect which states that productivity increases faster in tradable than in non-tradable sectors. This phenomenon augments wages in the tradable sector, consequently wages in the non-tradable sector. This implies an increase in domestic inflation and an appreciation of the REER. Hence we expect $\theta_2$ to be positive. Restricted trade has a downward effect on the relative price of tradable to non-tradable goods, leading therefore to an appreciation of the REER. Thus $\theta_3$ is supposed to be negative.

If we assume that all variables in equation (4.7) are *I(1)* and cointegrated then $\upsilon_{it}$ is *I(0)*. The error correction representation of equation (4.7) is given by:

$$\begin{aligned}\Delta Log(REER_{it}) = \phi_i \left[Log(REER_{it-1}) - \theta_0 - \theta_1 Log(TOT_{it}) - \theta_2 Log(GDPCAP_{it}) - \theta_3 Log(OPEN_{it})\right] \\ + \delta_{1i}\Delta Log(TOT_{it}) + \delta_{2i}\Delta Log(GDPCAP_{it}) + \delta_{3i}\Delta Log(OPEN_{it}) + \varepsilon_{it} \qquad (4.8)\end{aligned}$$

The parameter $\phi_i$ is the error-correcting speed of adjustment term. As mentioned above, we expect this parameter to be significantly negative implying that variables return to a long-run equilibrium. Of particular importance are the parameters $\theta_i$ which capture the long-term relationship between REER and the fundamentals. The results of the estimation of equation (4.8) are given in Table 4.4.

Table 4.4 shows that all parameters have the expected signs and are statistically significant. In particular the Adjustment coefficient is negative. This relationship between REER and the fundamentals is also cointegrated. For example the *Pedroni (1999)* panel data cointegration Panel-PP statistic and Group PP-statistic are respectively 0.0121 and 0.0178. This result and the negative sign of the Adjustment coefficient mean that the long-run value of REER stays around its equilibrium value. After estimating equation (4.8), we multiply the parameters

$\theta_i$ by the corresponding three year moving average of the corresponding fundamental. This result gives us the equilibrium REER (EREER). Then REER misalignment is then computed according to the following formula:

$$Misal_{it} = \frac{Log(REER_{it})}{Log(EREER_{it})} - 1 \quad (4.9)$$

In equation (4.9), a positive value of $Misal_{it}$ represents an overvaluation. There exist many determinants of equilibrium real exchange rate. We chose to use only these three fundamentals for simplicity reasons. We believe that three determinants allow us to incorporate in our present study the essence of equilibrium REER. The main focus of the paper is not the estimation of equilibrium REER. That is why we do not include more variables in the estimation of equilibrium REER. Notwithstanding the measurement of REER misalignment employed here is the first to be based on panel data cointegration techniques in the empirical link between REER misalignment and exports. Additionally, there are lots of studies that use a measure of REER misalignment based only on one variable. Also we employ the logarithm of real GDP per capita as a proxy of the *Balassa-Samuelson* effect as is done in many studies. An alternative measurement would be the ratio of the GDP per capital of the country and the GDP per capita of its trade partners. But this variable, as elaborate as it could be, is also a proxy variable not a true measurement of the *Balassa-Samuelson* effect. This is why we stick to the real GDP per capita as a measure of the *Balassa-Samuelson* phenomenon. To obtain the long-run values of the fundamentals we could employ the trends given by the Hodrick-Prescott filter. But the problem is that this filter cannot be employed in time series with gaps in the data. This is the reason why we use three year moving averages as long-term measurements of the values of the fundamentals. Again this way of proceeding is done by numerous researchers.

### 4.5.2 Measurement of Real Effective Exchange Rate Volatility

We compute real exchange rate volatility using ARCH family methods. Specifically we apply the asymmetric EGARCH (1, 1). The asymmetry implies that positive values of residuals have a different effect than negative ones. This is formulated as below:

$$Log(REER_t) - Log(REER_{t-1}) = \beta_0 + \varepsilon_t$$
$$Log(\sigma_t^2) = \gamma_0 + \gamma_1 \frac{|\varepsilon_{t-1}|}{\sqrt{\sigma_{t-1}^2}} + \delta_1 Log(\sigma_{t-1}^2) + \theta_1 \frac{\varepsilon_{t-1}}{\sqrt{\sigma_{t-1}^2}} \qquad (4.10)$$

Where $\varepsilon_t$ are distributed as $N(0, \sigma_t^2)$, $\sigma_t^2$ the variance of the regression model's disturbances, $\gamma_i$ the ARCH parameters, $\delta_1$ the GARCH parameter, $\theta_1$ the asymmetric EGARCH parameter. With this parameterization, a negative value of $\theta_1$ means that non-positive residuals produce higher variances in the near future. We measure the exchange rate volatility as the square root of the variance of the regression model's disturbances.

## 4.6 Panel data tests

In this section, we will successively present the panel unit root tests and the cointegration tests.

### 4.6.1 Panel Unit Root Tests

Table 4.5 gives the results of the unit root tests for all variables expressed in level. In all tests, the null hypothesis is that the series contains a unit root, and the alternative is that the series is stationary. The *Levin, Lin and Chu* and the *Breitung* tests make the simplifying assumption that the panels are homogenous while the other tests assume that the panels are heterogeneous. Excluding Log investment to GDP and REER volatility which are stationary[43], the tests show that all the other variables may contain unit root. Moreover Table 4.6 illustrates that these other variables are potentially *I(1)*. This last result leads us to the issue of cointegration among these variables.

### 4.6.2 Panel Cointegration Tests

Table 4.7 shows the panel data cointegration tests for the equations used in the main estimation results[44]. Among the panel cointegration tests, we utilize the *Pedroni (1999)* and *Kao (1999)* panel cointegration tests. In the *Pedroni (1999)* tests, the first three tests present the within dimension while the others give the between dimension. For the *Kao (1999)* tests, only the Dickey-Fuller type tests are shown. In all these tests, the Null Hypothesis is that there is No cointegration. Overall, the results illustrates that there exist a cointegration relationship for all equations.

## 4.7 Estimation Results

Table 4.8 presents the main estimation of the long-term coefficients that interest us. We know that the PMG estimator constrains the long-run elasticities to be equal across all panels. This PMG estimator is efficient and consistent while the Mean Group (MG) estimator, which assumes heterogeneity in both short-run and long-run coefficients, is consistent when the

[43] The Misalignment variable can also be considered as stationary because two tests out of four show that it is stationary.
[44] See Table 4.8 for the main estimation results.

restrictions are true. If the true model is heterogeneous, the PMG estimator is inconsistent while the MG estimator is consistent. We run a *Hausman* test to test for the difference between these two models in our sample of study. The P-values for the *Hausman* test in Table 4.8 show that we do not reject the Null hypothesis that the efficient estimator, the PMG estimator, is the desired one. The speed of adjustment parameter is negative and highly significant in all regressions and is approximately stable in magnitude. As mentioned above, this result suggests that the variables return to a long-run equilibrium.

All eight equations in Table 4.8 illustrate that REER misalignment and REER volatility are statistically significant and have the expected signs. We notice that the magnitude of REER misalignment is too low compared to that of REER volatility. This suggests that REER volatility is more harmful to exports than misalignment in our sample of study. The impact of REER volatility is very high. Referring to regression 4, an increase in REER volatility by one standard deviation reduces the ratio of exports to GDP by an amount approximately equivalent to 24%. These results corroborate those found by several studies like *Ghura and Grennes (1993)* and *Grobar (1993)*.

The results also highlight that exports are positively influenced by manufactured value added to GDP, GDP of trade partners, real GDP and investment to GDP. The Terms of trade, when they are significant, are also positively related to exports. The positive value of the coefficient of GDP of trade partners means that when the trade partners experience high growth, this results in a pulling effect on the exports of the home country. The positive effect of real GDP and investment to GDP means that exports increase when the productive capacity of a country rises.

# 4.8 Robustness Analysis

Table 4.9 and 4.10 give the estimations of the effects of REER misalignment and REER volatility on exports for the low income and middle income developing countries respectively. The results in the two table show that both REER misalignment and REER volatility affect negatively exports. This confirms the findings of our main estimations results. Also as in the main estimations, we observe that REER volatility is more harmful to exports than misalignment.

# 4.9 Conclusion

We studied the effects of REER misalignment and REER volatility on exports for 42 developing countries from 1975 to 2004. Using new developments on panel data cointegration techniques, we found that both REER misalignment and REER volatility have a strong negative impact of exports. But the effect of REER misalignment is smaller than that of REER volatility. The impact of REER volatility is very high: an increase in REER volatility by one standard deviation reduces the ratio of exports to GDP by an amount approximately equivalent to 24%.

Although the results found were informative, some caveats remain. First, we did not analyze the effect of REER misalignment and REER volatility on manufactured exports and for developed countries. Second, the fact that REER misalignment is a generated regressor could cause some bias in the estimation results, especially in the standards errors of the regressions.

From policy perspectives, the results show that macroeconomic instability, in particular exchange rate volatility could have negative impacts on exports and that efforts made to reduce them might relaunch exports and productivity.

It is important to notice that we used different REER volatilities and econometrics techniques throughout the chapters. This is done for robustness purposes and to broaden the range of choices. One may wonder why we did not employ only one measurement of REER volatility and one econometric method. While this way of proceeding may look good at the first place, it could make our exposition very poor and sterilized. We could hardly learn what we have learned by adopting this process. This is principally why we employed different measurements of REER volatility and econometric techniques.

# Appendices of Chapter 4

## Table 4.1: Definitions and methods of calculation of the variables

| Variables | Definitions | Expected Sign | Sources of data |
|---|---|---|---|
| Log exports to GDP | Total Exports divided by GDP | | |
| Log manufactured value added to GDP | Logarithm of Manufactured value added over GDP | Positive | World Bank, World Development Indicators, 2004 |
| Log GDP of trade partners | Logarithm of the GDP of trade partners. The trade partners are the same as those used to calculate the REER | Positive | Author calculations |
| Log terms of trade | Logarithm of the terms of trade | Positive or Negative | World Bank, World Development Indicators, 2004 |
| Log real GDP | Logarithm of the real GDP | Positive | |
| Log investment to GDP | Logarithm of the total Investment to GDP | Positive | |

## Table 4.2: Summary statistics on variables

| Variables | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Log exports to GDP | 1259 | -1.4201 | 0.6245 | -3.5422 | 0.2184 |
| Misalignment | 1136 | 23.2513 | 896.0622 | -8108.7380 | 27431.8100 |
| REER volatility | 1241 | 0.1531 | 0.3056 | 0.0003 | 7.1438 |
| Log manufactured value added to GDP | 1185 | -1.9430 | 0.4992 | -3.6892 | -0.8988 |
| Log GDP of trade partners | 1260 | 30.3331 | 1.1001 | 26.5335 | 32.3573 |
| Log terms of trade | 1249 | 0.0517 | 0.2627 | -0.9333 | 1.8050 |
| Log real GDP | 1260 | 22.9255 | 1.9825 | 18.5565 | 28.1704 |
| Log investment to GDP | 1258 | -1.5386 | 0.3572 | -3.3880 | -0.3080 |

# **Table 4.3:** List of 42 countries

| No. | World Bank Code | Countries | No. | World Bank Code | Countries |
|---|---|---|---|---|---|
| 1 | ARG | Argentina | 22 | HND | Honduras |
| 2 | BDI | Burundi | 23 | HUN | Hungary |
| 3 | BEN | Benin | 24 | IDN | Indonesia |
| 4 | BFA | Burkina Faso | 25 | IND | India |
| 5 | BGD | Bangladesh | 26 | KEN | Kenya |
| 6 | BOL | Bolivia | 27 | LKA | Sri Lanka |
| 7 | CHL | Chile | 28 | LSO | Lesotho |
| 8 | CHN | China | 29 | MAR | Morocco |
| 9 | CIV | Cote d'Ivoire | 30 | MEX | Mexico |
| 10 | CMR | Cameroon | 31 | MLI | Mali |
| 11 | COG | Congo, Rep. | 32 | MRT | Mauritania |
| 12 | COL | Colombia | 33 | MWI | Malawi |
| 13 | CRI | Costa Rica | 34 | MYS | Malaysia |
| 14 | DOM | Dominican Republic | 35 | NIC | Nicaragua |
| 15 | DZA | Algeria | 36 | PER | Peru |
| 16 | ECU | Ecuador | 37 | PHL | Philippines |
| 17 | GAB | Gabon | 38 | PRY | Paraguay |
| 18 | GHA | Ghana | 39 | SEN | Senegal |
| 19 | GMB | Gambia, The | 40 | SWZ | Swaziland |
| 20 | GNB | Guinea-Bissau | 41 | TGO | Togo |
| 21 | GTM | Guatemala | 42 | THA | Thailand |

# Table 4.4: Estimation of Equilibrium Real Effective Exchange Rate

| Dependent Variable: Log(REER) | |
|---|---|
| Regressors | |
| Adjustment coefficient | -0.136*** |
| | (-7.470) |
| Log terms of trade | 0.343*** |
| | (8.811) |
| Log real GDP per Capita | 0.156* |
| | (1.911) |
| Log openness | -0.268*** |
| | (-4.432) |
| Constant | 0.487*** |
| | (7.151) |
| Observations | 1,085 |

Note: z-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# **Table 4.5:** Panel unit root tests (Level of variables)

| Variables | Levin, Lin and Chu t | Breitung t-stat | Im, Pesaran and Shin W-stat | Maddala Wu ADF-Fisher Chi-square |
|---|---|---|---|---|
| Log exports to GDP | 0.4990 | -12.8756 | -1.1752 | 70.0695 |
| | (0.6911) | (0.0000) | (0.1200) | (0.8618) |
| misalignment | -1.1166 | -4.2965 | -14.4034 | 16.3843 |
| | (0.1321) | (0.0000) | (0.0000) | (0.1743) |
| REER volatility | -19.5993 | -12.8756 | -15.7458 | 277.0994 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Log manufactured value added to GDP | -1.0035 | 1.5786 | -1.0080 | 103.0233 |
| | (0.1578) | (0.9428) | (0.1567) | (0.0014) |
| Log GDP of trade partners | 1.3394 | 3.7455 | 3.4090 | 53.9241 |
| | (0.9098) | (0.9999) | (0.9997) | (0.9956) |
| Log terms of trade | -1.1245 | -0.0145 | -2.5253 | 111.3942 |
| | (0.1304) | (0.4942) | (0.0058) | (0.0032) |
| Log real GDP | -1.0386 | -0.2293 | 1.9469 | 87.8968 |
| | (0.1495) | (0.4093) | (0.9742) | (0.3080) |
| Log investment to GDP | -5.4324 | -3.9206 | -5.7130 | 178.3153 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |

Note: P-values in Brackets. The Null hypothesis is that the panels contain unit roots

## **Table 4.6:** Panel unit root tests (First Difference of variables)

| Variables | Levin, Lin and Chu t | Breitung t-stat | Im, Pesaran and Shin W-stat | Maddala Wu ADF-Fisher Chi-square |
|---|---|---|---|---|
| Log exports to GDP | -18.1706 | -0.1404 | -15.2702 | 274.9849 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Misalignment | -18.3933 | -12.2606 | -19.0620 | 408.2912 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| REER volatility | -23.7210 | -16.2836 | -23.4247 | 607.5081 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Log manufactured value added to GDP | -12.5258 | -14.1484 | -16.2908 | 250.0973 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Log GDP of trade partners | -9.2737 | -11.3343 | -14.8460 | 330.2056 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Log terms of trade | -10.1566 | -11.7080 | -18.8771 | 411.0109 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Log real GDP | -7.2227 | -10.8260 | -15.3636 | 255.9766 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Log investment to GDP | -10.6587 | -13.2450 | -19.2599 | 472.4241 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) |

Note: P-values in Brackets. The Null hypothesis is that the panels contain unit roots

## Table 4.7: Panel data cointegration tests

| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|---|---|
| Pedroni Panel Cointegration Tests | Within Dimension | Panel rho-Statistic | 0.1571 | 0.1571 | -0.0279 | -0.5009 | 0.6601 | -2.0830 | -2.1244 | 0.2260 |
| | | | (0.5624) | (0.5624) | (0.4889) | (0.3082) | (0.7454) | (0.0186) | (0.0168) | (0.5894) |
| | | Panel PP-Statistic | -5.0846 | -5.0846 | -2.9607 | -4.3886 | -7.0129 | -5.6516 | -7.1082 | -7.3083 |
| | | | (0.0000) | (0.0000) | (0.0015) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| | | Panel ADF-Statistic | -3.5449 | -3.5449 | -0.0721 | -2.4110 | -5.9029 | -3.7485 | -4.3161 | -7.6276 |
| | | | (0.0002) | (0.0002) | (0.4713) | (0.0080) | (0.0000) | (0.0001) | (0.0000) | (0.0000) |
| | Between Dimension | Group rho-Statistic | 1.3613 | 1.3613 | 0.5603 | 2.6506 | 2.4616 | 0.0200 | 1.5413 | 2.3543 |
| | | | (0.9133) | (0.9133) | (0.7124) | (0.9960) | (0.9931) | (0.5080) | (0.9384) | (0.9907) |
| | | Group PP-Statistic | -5.6116 | -5.6116 | -4.7888 | -3.8288 | -9.1940 | -6.3894 | -6.1122 | -8.7235 |
| | | | (0.0000) | (0.0000) | (0.0000) | (0.0001) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| | | Group ADF-Statistic | -3.4324 | -3.4324 | -1.5013 | -2.1624 | -6.9145 | -4.1617 | -2.8691 | -7.1556 |
| | | | (0.0003) | (0.0003) | (0.0666) | (0.0153) | (0.0000) | (0.0000) | (0.0021) | (0.0000) |
| Kao Panel Cointegration Tests | | DF t-Statistic | -3.7431 | -3.7431 | -1.8391 | -4.2065 | | -4.2902 | -5.0981 | -4.0746 |
| | | | (0.0001) | (0.0001) | (0.0329) | (0.0000) | | (0.0000) | (0.0000) | (0.0000) |
| | | DF* t-Statistic | -2.1313 | -2.1313 | -0.9426 | -2.6841 | | -2.6884 | -3.5300 | |
| | | | (0.0165) | (0.0165) | (0.1729) | (0.0036) | | (0.0036) | (0.0002) | |

Note: P-values in parentheses.
The Null Hypothesis is that there is No cointegration

## **Table 4.8:** Panel data cointegration estimation results

| Dependent Variable: Log Exports to GDP | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regressors | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Adjustment coefficient | -0.220*** | -0.220*** | -0.181*** | -0.210*** | -0.206*** | -0.245*** | -0.216*** | -0.245*** |
| | (-6.202) | (-6.202) | (-4.292) | (-5.556) | (-5.519) | (-6.374) | (-5.026) | (-7.140) |
| Misalignment | | | -0.000783*** | -0.000734*** | -0.000334** | -0.000358*** | -0.000569*** | -0.000199* |
| | | | (-8.440) | (-8.830) | (-2.559) | (-2.677) | (-4.441) | (-1.890) |
| REER volatility | -0.350*** | -0.350*** | -0.584*** | -0.778*** | -0.434*** | | | |
| | (-4.597) | (-4.597) | (-5.800) | (-8.214) | (-4.892) | | | |
| Log manufactured value added to GDP | 0.196*** | 0.196*** | | | 0.0627 | | | 0.0587* |
| | (3.705) | (3.705) | | | (1.604) | | | (1.726) |
| Log GDP of trade partners | 0.586*** | 0.586*** | | 0.784*** | 0.814*** | 0.797*** | 0.868*** | 0.641*** |
| | (10.30) | (10.30) | | (17.52) | (16.40) | (19.29) | (21.79) | (6.686) |
| Log terms of trade | -0.00340 | -0.00340 | 0.261*** | 0.0357 | 0.122*** | 0.0981*** | 0.153*** | 0.144*** |
| | (-0.0494) | (-0.0494) | (15.79) | (1.483) | (3.263) | (2.698) | (4.978) | (5.063) |
| Log real GDP | | | | | | | | 0.241*** |
| | | | | | | | | (3.228) |
| Log investment to GDP | | | | | | | 0.126*** | |
| | | | | | | | (3.573) | |
| Constant | -4.149*** | -4.149*** | -0.246*** | -5.303*** | -5.356*** | -6.295*** | -5.989*** | -6.479*** |
| | (-6.158) | (-6.158) | (-3.169) | (-5.497) | (-5.450) | (-6.276) | (-4.957) | (-7.081) |
| Observations | 1,111 | 1,111 | 1,068 | 1,068 | 1,012 | 1,085 | 1,085 | 1,029 |
| Hausman Test | 6.05 | 6.05 | 0.63 | | | 1.43 | 0.39 | 0.24 |
| P-value | [0.1958] | [0.1958] | [0.7283] | | | [0.4885] | [0.5305] | [0.622] |

Note: z-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

# **Table 4.9:** Estimation Results for Low-Income Countries

Dependent Variable: Log Exports to GDP

| Regressors | (1) | (2) | (3) |
|---|---|---|---|
| Adjustment coefficient | -0.306*** | -0.281*** | -0.318*** |
| | (-4.197) | (-3.562) | (-2.832) |
| Misalignment | -0.000691*** | -0.000772*** | -0.000694*** |
| | (-8.450) | (-8.084) | (-3.657) |
| REER volatility | -1.008*** | -0.527*** | -0.828*** |
| | (-8.787) | (-4.803) | (-4.971) |
| Log GDP of trade partners | 0.731*** | | |
| | (15.30) | | |
| Log terms of trade | | 0.266*** | |
| | | (15.89) | |
| Log real GDP | | | 0.861*** |
| | | | (23.72) |
| Log investment to GDP | | | 0.182*** |
| | | | (4.335) |
| Constant | -7.232*** | -0.413*** | -6.828** |
| | (-4.119) | (-2.598) | (-2.507) |
| Observations | 455 | 451 | 455 |

Note: z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

## <u>Table 4.10:</u> Estimation Results for Middle-Income Countries

Dependent Variable: Log Exports to GDP

| Regressors | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Adjustment coefficient | -0.218*** | -0.227*** | -0.0815** | -0.0957** | -0.243*** | -0.217*** | -0.203*** | -0.191*** |
| | (-5.914) | (-5.229) | (-2.402) | (-2.484) | (-6.499) | (-5.969) | (-5.500) | (-4.671) |
| Misalignment | -0.000576*** | -0.000745** | -0.00165*** | -0.00449** | -0.000457*** | | | |
| | (-3.752) | (-2.572) | (-2.622) | (-2.491) | (-3.917) | | | |
| REER volatility | -0.549*** | -0.585*** | -0.738*** | -0.924*** | | -0.411*** | -0.567*** | -0.345*** |
| | (-2.870) | (-2.667) | (-3.927) | (-2.827) | | (-2.699) | (-3.841) | (-3.433) |
| Log real GDP | 0.355*** | 0.493*** | | | 0.535*** | 0.387*** | 0.292*** | |
| | (6.489) | (11.55) | | | (15.57) | (7.014) | (2.884) | |
| Log manufactured value added to GDP | | 0.283*** | 0.485** | | 0.240** | | | 0.762*** |
| | | (2.738) | (2.564) | | (2.560) | | | (10.80) |
| Log investment to GDP | | | 0.647*** | 0.593*** | | | | |
| | | | (7.271) | (4.418) | | | | |
| Log GDP of trade partners | | | | 0.896*** | | | 0.564*** | 1.101*** |
| | | | | (11.31) | | | (3.490) | (19.18) |
| Log terms of trade | | | | -0.159 | -0.313*** | | | 0.145* |
| | | | | (-0.950) | (-2.956) | | | (1.948) |
| Constant | -2.038*** | -2.797*** | 0.0777*** | -2.685** | -3.335*** | -2.196*** | -5.149*** | -6.526*** |
| | (-5.857) | (-5.074) | (2.952) | (-2.498) | (-6.366) | (-6.102) | (-5.697) | (-4.724) |
| Observations | 619 | 596 | 596 | 617 | 599 | 660 | 660 | 632 |

Note: z-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

# General Conclusion

TFP is crucial in the discussions on the sources of economic growth. Most studies illustrate that TFP account for at least ⅓ of the overall GDP growth in most countries. Both neoclassical and endogenous growth theories defend that the importance of TFP in the process of economic growth cannot be ignored. Similarly to TFP, the real exchange rate and its associated measurements play an important role in the economy. This thesis is one of the first studies to investigate the theoretical and empirical relationships between these two variables. Hence, this dissertation analyzes how the REER and its associated measurements affect productivity.

The first part of the dissertation analyzes how the REER and its associated measurements affect TFP. It specifically studies how the REER itself, on the one hand, and the REER volatility, on the other hand, act on TFP or TFPG. The second part examines the channels through which the REER and its associated measurements (REER volatility and REER misalignment) influence TFP in two chapters. The first one explores the REER volatility-investment nexus while the second one investigates the connection between REER misalignment, REER volatility and total exports.

- ***The Main Results:***

We explore in chapter 1 how the REER itself affects TFP. This investigation demonstrates that an appreciation of the REER increases TFP. The impact of REER on productivity is very high. By supposing a variation expressed in percentage rate of real effective exchange of 35%, the corresponding rise of the total factor productivity is 4%. The results also illustrates that this effects of real exchange rate on productivity is nonlinear. Under the threshold, real exchange rate acts negatively on productivity while above the threshold real exchange rate has a positive effect on productivity. After studying the impact of the level of REER on TFP, the analysis of the connection between REER volatility and TFPG in chapter 2 shows that REER volatility acts on productivity according to some threshold variable: financial development or liability dollarization. Using panel data instrumental variables and threshold effects estimation methods, we first found that REER volatility affects negativity total factor productivity growth and second, we discovered that this impact of REER volatility depends on the level of financial development of the countries. For very low and very high levels of financial development, REER volatility has no effect on productivity growth but for moderately financially developed countries, REER volatility reacts negatively on productivity. Chapter 3 represents our first attempt to examine the channels through which the REER or its associated measurements affect productivity. This chapter examines the relation between the real exchange rate, its volatility and investment both theoretically and empirically. The theoretical part of the chapter indicates that real exchange rate and real exchange rate volatility have nonlinear effects on investment. Using new developments on panel data cointegration techniques, we find that REER volatility has a strong negative impact of investment. An increase in REER volatility by one standard deviation reduces the ratio of investment to lagged capital stock by an amount approximately equivalent to eight standard deviations. The robustness checks illustrates that this negative impact of REER volatility on investment is stable to the use of an alternative measurement of REER volatility and on subsamples of developing countries (low-income and middle-income countries). We continue to explore the transmission channels of REER and its associated measurements to productivity in chapter 4 by studying the connection between the REER misalignment, REER volatility and exports. Using new developments on panel data cointegration techniques, we found that both REER misalignment and REER volatility have a strong negative impact of exports. But the effect of REER misalignment is smaller than that of REER volatility. The impact of REER volatility is very high: an increase in REER volatility by one standard deviation reduces the ratio of exports to GDP by an amount approximately equivalent to 24%.

- ***Economic Policy Implications:***

The policy implications of our analysis in this thesis suggest that high REER volatility and large REER misalignments must be avoided. It is important to keep REER volatility and REER misalignment low not only in the short but also in the medium and long-run in order to boost productivity and economic growth. It is important to keep REER appreciation very low for countries below some level of REER and increase REER appreciation for economies above this threshold in order to augment productivity and growth. Keeping REER misalignment very low augment domestic investment, Foreign Direct Investment (FDI) and exports, all of which, increase TFP and growth. Lower misalignment enhances economic efficiency and prevents misallocation of resources. Undervaluation raises the profitability of the tradable sector, and leads to an extension of the share of tradable in domestic value added. This in turn encourages investment in the tradable sector and improves productivity and economic growth. Reducing REER instability allows plummeting uncertainty on the profitability of producing tradable goods and of long-run investment. It also helps diminishing the jamming signals sent to agents. All this increase productivity and growth. The impact of REER volatility on economic performance is function of the level of financial development. Countries that have very low and very high levels of financial development, REER volatility might not be an obstacle to economic performance but moderately financially developed countries should drastically reduce REER volatility in order to boost productivity. Countries should also keep a stable macroeconomic environment if they want to lessen the detrimental effects of the REER volatility on macroeconomic performance. Finally, in the long-run, countries should diminish the instability of the REER if they want to raise investment and exports, which constitute essential factors of TFPG and economic growth in general.

- ***Possible Extensions:***

Although the results found in this thesis were illuminating, some extensions deserve to be underlined.

Firstly, in chapter 1, we may perhaps expand the sample of study to examine the possible existence of a negative short-term impact of REER on productivity. In chapter 2, we could include liability dollarization or an equivalent measurement beside financial development as a threshold variable. In chapter 3, if data on both public and private investment are available, some regressions on these two variables would allow us to compare the effects of REER volatility between these two variables and domestic investment. In chapter 4, we might analyze the effect of REER misalignment and REER volatility on manufactured exports and for developed countries. In this chapter, we may well employ a gravity model in analyzing the impact of the associated measurements of REER on exports.

Secondly, we might employ a threshold effect estimation method that takes into account both the unobservable heterogeneity of the countries and the endogeneity of REER or its associated measurements in chapters 1 and 2[45]. We could also employ the Panel Smooth Transition Regression technique to tackle the nonlinearity in the relationships between the REER or its associated measurements and productivity[46]. In chapter 3, some studies on structural change in the context of panel cointegration could also provide helpful information on the impact of REER volatility on investment. In chapter 4, the fact that REER misalignment is a generated regressor

[45] There does not exist, to this date, a method of estimation of threshold effects with instrumental variables on panel data
[46] My attempt to get the programs that implements this method from the authors failed since they did not gave me any response.

could cause some bias in the estimation results, especially in the standards errors of the regressions. Hence some bootstrapping might reduce the bias in the estimations.

Thirdly, we should explore the impact of REER or its associated measurements on the components of TFP (technical change, scale effect, technical efficiency change and allocative inefficiency).

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# Computer code for calculating physical capital stock

In this part of the thesis, we list the computer program used to calculate the physical capital stock by the perpetual-inventory method. The entire code is downloadable at:

**http://ideas.repec.org/c/boc/bocode/s457270.html**

The command is also downloadable from within Stata by typing (you must be connected to Internet for this action to work):

```
ssc install stockcapit
ssc install tsspell, replace
```

Here is the code:

```
*! stockcapit version 1.0.2
*! Computes Physical Capital Stock
*! Diallo Ibrahima Amadou
*! All comments are welcome, 2011


capture program drop stockcapit
program stockcapit, rclass sortpreserve
        version 10
        syntax varlist(min=2 max=2) [if] [in] , CAPITal(string) [DELTA(real 0.05)]
        qui tsset
        local panelvar "`r(panelvar)'"
        local timevar  "`r(timevar)'"
        tempfile maindata sampledata
        if "`panelvar'" == ""    {
                                 sort `timevar'
                                 qui save `maindata',replace
        }
        else {
              sort `panelvar' `timevar'
              qui save `maindata',replace
        }
        marksample touse
        qui count if `touse'
        if r(N) == 0 {
                      di as err "No observations."
                      exit 2000
```

```
        }
        foreach x of varlist `varlist' {
                                        qui replace `touse' = 0 if `x' >= .
        }
        qui keep if `touse'
        gettoken inv gdp : varlist
        tempvar kap invmeam croisimeam indic lengthp maxrunp select decision ///
 verif valgdpinit valgdpfinal meanvalgdpinit meanvalgdpfinal
        confirm new var `capital'
        qui capture drop  _spell _seq _end
        if "`panelvar'" == ""   {
                                quietly {
                                        tsset
                                        tsspell, f(L.`timevar' == .)
                                        bysort  _spell: egen `lengthp' = max(_seq)
                                        egen `maxrunp' = max(_seq)
                                        gen `select' = cond(`maxrunp' ///
== `lengthp',1,0)
                                        gen `decision' = 0
                                        replace `decision' = sum(`select') ///
if `select' == 1
                                        egen `verif' = max(`decision')
                                        replace  `decision' = 0 if  `verif'< 5
                                        sort `timevar'
                                        tsset
                                        gen double `valgdpinit'  = `gdp' ///
if `decision' == 1 & `touse'
                                        gen double `valgdpfinal' = `gdp' if ///
`decision' == 5 & `touse'
                                        egen double `meanvalgdpinit'  ///
= mean(`valgdpinit') if `touse'
                                        egen double `meanvalgdpfinal' ///
= mean(`valgdpfinal') if `touse'
                                        gen double `croisimeam'   ///
= ((`meanvalgdpfinal'/`meanvalgdpinit')^(1/5)) - 1 if `decision' >= 1 & ///
`decision' <= 5 &  `touse'
                                        egen double `invmeam'   ///
 = mean(`inv') if `decision' >= 1 & `decision' <= 5 &  `touse'
                                        gen double `kap'         = .
                                        replace    `kap'       ///
= `invmeam'/(`croisimeam' + `delta') if `decision' == 1 & `touse'
```

```
                                          replace    `kap'         = L.`kap' + ///
L.`inv' - `delta'*(L.`kap') if `decision' > 1 & `touse'
                                          rename `kap' `capital'
                                   }
        }
        else {
              quietly {
                       tsset
                       tsspell, f(L.`timevar' == .)
                       bysort `panelvar' _spell: egen `lengthp' = max(_seq)
                       bysort `panelvar': egen `maxrunp' = max(_seq)
                       gen `select' = cond(`maxrunp' == `lengthp',1,0)
                       bysort `panelvar': gen `decision' = 0
                       bysort `panelvar': replace `decision' ///
= sum(`select') if `select' == 1
                       bysort `panelvar': egen `verif' = max(`decision')
                       bysort `panelvar': replace  `decision' = 0 if  `verif'< 5
                       sort `panelvar' `timevar'
                       tsset
                       by `panelvar' : gen double `valgdpinit'  = `gdp' ///
if `decision' == 1 & `touse'
                       by `panelvar' : gen double `valgdpfinal' = `gdp' ///
if `decision' == 5 & `touse'
                       by `panelvar' : egen double `meanvalgdpinit' ///
=  mean(`valgdpinit') if `touse'
                       by `panelvar' : egen double `meanvalgdpfinal' ///
= mean(`valgdpfinal') if `touse'
                       by `panelvar' : gen `indic'              = 0
                       by `panelvar' : replace `indic'          = 1 ///
if  `decision' >= 1 & `decision' <= 5 & `touse'
                       by `panelvar' : gen double `croisimeam'   ///
= ((`meanvalgdpfinal'/`meanvalgdpinit')^(1/5)) - 1  if `indic' == 1
                       by `panelvar' : egen double `invmeam'   ///
= mean(`inv')    if `indic' == 1
                       by `panelvar' : gen double `kap'         = .
                       by `panelvar' : replace    `kap'      ///
= `invmeam'/(`croisimeam' + `delta') if `decision' == 1 & `touse'
                       by `panelvar' : replace    `kap'      ///
= L.`kap' + L.`inv' - `delta'*(L.`kap') if `decision' > 1 & `touse'
                       rename `kap' `capital'
              }
        }
```

```
        qui drop  _spell _seq _end
        qui capture drop if `capital' < 0
        if "`panelvar'" == ""   {
                                sort `timevar'
                                qui keep `timevar' `capital'
                                qui save `sampledata',replace
                                capture clear
                                qui use `maindata', clear
                                merge `timevar' using `sampledata'
                                qui drop _merge
        }
        else {
              sort `panelvar' `timevar'
              qui keep `panelvar' `timevar' `capital'
              qui save `sampledata',replace
              capture clear
              qui use `maindata', clear
              merge `panelvar' `timevar' using `sampledata'
              qui drop _merge
        }
        label var `capital' "Calculated Physical Capital Stock"
        return local capital "`capital'"
end
```

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## RESUMÉ

Cette thèse étudie comment le taux de change effectif réel (TCER) et ses mesures associées (volatilité du TCER et désalignement du TCER) affectent la croissance de la productivité totale des facteurs (CPTF). Elle analyse également les canaux par lesquels le TCER et ses mesures associées agissent sur la productivité totale des facteurs (PTF). La première partie étudie comment le TCER lui-même, d'une part, et la volatilité du TCER, d'autre part, influencent la productivité. Une analyse du lien entre le niveau du TCER et la PTF dans le chapitre 1 indique qu'une appréciation de taux de change cause une augmentation de la PTF. Mais cet impact est également non-linéaire: en-dessous du seuil, le TCER influence négativement la productivité tandis qu'au-dessus du seuil il agit positivement. Les résultats du chapitre 2 illustrent que la volatilité du TCER affecte négativement la CPTF. Nous avons également constaté que la volatilité du TCER agit sur PTF selon le niveau du développement financier. Pour les pays modérément financièrement développés, la volatilité du TCER réagit négativement sur la productivité et n'a aucun effet sur la productivité pour les niveaux très bas et très élevés du développement financier. La deuxième partie examine les canaux par lesquels le TCER et ses mesures associées influencent la productivité. Les résultats du chapitre 3 illustrent que la volatilité du TCER a un impact négatif élevé sur l'investissement. Ces résultats sont robustes dans les pays à faible revenu et les pays à revenu moyens, et en employant une mesure alternative de volatilité du TCER. Le chapitre 4 montre que le désalignement du taux de change réel et la volatilité du taux de change réel affectent négativement les exportations. Il démontre également que la volatilité du taux de change réel est plus nocive aux exportations que le désalignement. Ces résultats sont corroborés par des résultats sur des sous-échantillons de pays à bas revenu et à revenu moyen.



***MOTS CLÉS:*** *Appréciation; Biens D'Investissement; Amortissement; Optimisation Dynamique; Volatilité Du Taux De Change; Taux De Change; Exportations, Investissement; Désalignement; Cointégration En Données De Panel; Régression Avec Variable Instrumentale En Données De Panel; Estimateur Pooled Mean Group; Taux De Change Effectif Réel , Analyse De Frontière Stochastique; Estimation D'Effets De Seuil ; Productivité Totale Des Facteurs, Volatilité;*

***CLASSIFICATION JEL:*** *F13, F3, F31, F41, O11, O16, O19, O24, O47, O57*

## ABSTRACT

This dissertation investigates how the real effective exchange rate (REER) and its associated measurements (REER volatility and REER misalignment) affect total factor productivity growth (TFPG). It also analyzes the channels through which the REER and its associated measurements act on total factor productivity (TFP). The first part studies how the REER itself, on the one hand, and the REER volatility, on the other hand, influence productivity. An analysis of the link between the level of REER and TFP in chapter 1 reveals that an exchange rate appreciation causes an increase of TFP. But this impact is also nonlinear: below the threshold, real exchange rate influences negatively productivity while above the threshold it acts positively. The results of chapter 2 illustrate that REER volatility affects negatively TFPG. We also found that REER volatility acts on TFP according to the level of financial development. For moderately financially developed countries, REER volatility reacts negatively on productivity and has no effect on productivity for very low and very high levels of financial development. The second part examines the channels through which the REER and its associated measurements influence productivity. The results of chapter 3 illustrate that the exchange rate volatility has a strong negative impact on investment. This outcome is robust in low income and middle income countries, and by using an alternative measurement of exchange rate volatility. Chapter 4 show that both real exchange rate misalignment and real exchange rate volatility affect negatively exports. It also demonstrates that real exchange rate volatility is more harmful to exports than misalignment. These outcomes are corroborated by estimations on subsamples of Low-Income and Middle-Income countries.



***KEYWORDS:*** *Appreciation; Capital Goods; Depreciation; Dynamic Optimization; Exchange Rate Volatility; Exchange Rate; Exports; Investment; Misalignment; Panel Data Cointegration; Panel Data Instrumental variable Regression; Pooled Mean Group Estimator; Real Effective Exchange Rate; Stochastic Frontier Analysis; Threshold Effect Estimation; Total Factor Productivity Growth; Volatility;*

***JEL CLASSIFICATION:*** *F13, F3, F31, F41, O11, O16, O19, O24, O47, O57*